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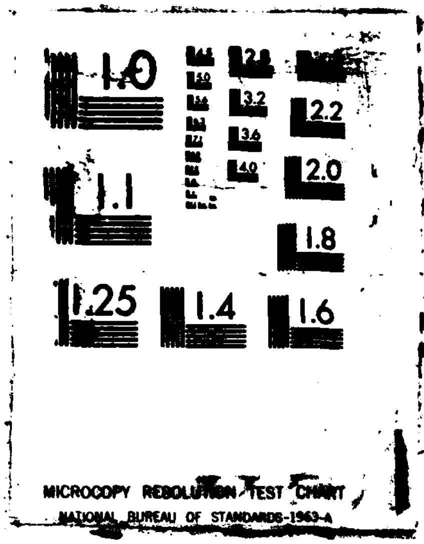
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AD-A182 553

COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT [illegible]

USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL ANALYSIS OF U-FRAME STRUCTURES (CUFRAM)

by

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INFORMATION TECHNOLOGY LABORATORY

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The computer program CUFRAM, described in this user's guide, performs an analysis of a two-dimensional slice of a U-frame structure. The program functions in two modes, equilibrium and frame analysis.

In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and determines the necessary base-reaction distribution to equilibrate the external loads. In the frame analysis mode, a model of the structure is formulated and displacements and internal forces throughout the structure are determined from a linearly elastic analysis.

Information regarding the response of the structure is provided by this program with no actual design functions nor judgment offered as to the quality of the structural performance. Under certain conditions outlined herein, an analysis of a two-dimensional slice provides comparatively reliable indications concerning the behavior of the three-dimensional system.

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6a. NAME OF PERFORMING ORGANIZATION (Continued)

Locks Subgroup, U-FRAME Structures Task Group
Computer-Aided Structural Engineering Project

PROGRAM INFORMATION

Description of Program

CUFRAM, called X0091 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library, is a computer program for the 2-D analysis of U-frame structures. It is intended to be an easy-to-use program incorporating many capabilities required by a diverse group of users. This program may be used to perform equilibrium and frame analyses of a two-dimensional slice of a soil- or pile-founded U-frame structure. An equilibrium analysis consists of converting soil and water data to structural loading and determining the resultants of all loads, including base reaction for a soil foundation. A frame analysis consists of establishing a plane frame model of the slice and determining displacements and internal forces throughout the structure.

Coding and Data Format

CUFRAM is written in FORTRAN and is operational on the following systems:

a. WES Honeywell DPS/8.

b. Local District Harris 500 Series.

c. Control Data Corporation's Cybernet system, Cyber 865.

Data can be input interactively at execute time or from a prepared data file with line numbers. Output may be directed to an output file or come directly back to the terminal.

How to Use CUFRAM

A short description of how to access the program on each of the three systems is provided below. It is assumed that the user knows how to sign on the appropriate system before trying to use CUFRAM. In the example initiation of execution commands below, all user responses are underlined, and each should be followed by a carriage return.

WES Honeywell System

The user signs on the system and issues the run command

FRN WESLIB/CORPS/X0091,R

to initiate execution of the program. The program is then run as described in this user's guide. The data file should be prepared prior to issuing the FRN command. An example initiation of execution is as follows, assuming a data file had previously been prepared:

COEWES HIS TIMESHARING ON 12/15/86 AT 11.175 CHANNEL Ø145 TS2
USER ID --RØKACLA
PASSWORD--

*USERS=Ø2Ø SS=Ø251K %MEM-USED=Ø68 ØØØ-WAIT-ØØØK
1Ø.187**ALL USERS SEE INFO SIGNON FOR WONDERFULLY GOOD NEWS!!!*******
*FRN WESLIB/CORPS/XØØ91,R

Control Data Corporation
Cybernet CYBER System

The log-on procedure is followed by a call to the CORPS procedure file

OLD,CORPS/UN=CECELB

to access the CORPS library. The file name of the program is used in the command

BEGIN,,CORPS,XØØ91

to initiate execution of the program. An example is:

CONNECTED TO 1Ø-17
86/12/15 11.1Ø.35 AC2DSHA
SN9Ø6 SCIENTIFIC INFORMATION SERVICE   NOS1.4-531-795-1
FAMILY' KOE,CERØC2
USER NAME' CERØF8
PASSWORD

TERMINAL'   6, NAMIAF
RECOVER/ CHARGE' CHARGE,CERØGC,CERØF8
$CHARGE,CERØEGC,CERØF8.
/
1Ø.36.21. WARNING

12/15/86, SEE EXPLAIN, WARNING.
OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,XØØ91

Harris System

The user signs on the system and issues the run command

*CORPS,XØØ91

to initiate execution of the program.

An example is:

"ACOE-WES(H5ØØ V5.1.1)"
ENTER SIGN-ON
11KABC ROKABC

```
** GOOD MORNING CORPS-LIB, IT'S 15 DEC 86 11:42:30
WES HARRIS 500  FOR SYSTEM INFORMATION - ENTER *NEWS
*CORPS,X0091
```

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the WES system is:

```
FRN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

On the Boeing system, the commands are:

```
OLD,CORPS/UN=CECELB
CALL,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM	PROGRAM NO.
Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	713-F3-RØØ91

PREPARING AGENCY

AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM: PHASE	STATUS OF PROGRAM: STAGE
William P. Dawkins	October 1986	Final	OP

A. PURPOSE OF PROGRAM

This program may be used to perform equilibrium and frame analyses of a two-dimensional slice of a soil- or pile-founded U-frame structure. An equilibrium analysis consists of converting soil and water data to structural loading and determining the resultants of all loads, including base reaction for a soil foundation. A frame analysis consists of establishing a plane frame model of the slice and determining displacements and internal forces throughout the structure.

B. PROGRAM SPECIFICATIONS

Timesharing FORTRAN Program.

C. METHODS

Equilibrium of soil-founded structures is established using one of three automatically generated base reaction distributions or a user-prescribed distribution adjusted to account for unbalanced loads. Pile stiffness matrices for pile-founded structures are obtained from a beam-column analysis for each pile. Frame analysis is performed using conventional matrix analysis procedures based on assumed linearly elastic behavior including the effects of shear deformations.

D. EQUIPMENT DETAILS

E. INPUT-OUTPUT

Data may be input from a prepared data file or from the user's terminal during execution. When data are supplied from the user's terminal, prompts are provided to indicate the amount and type of data to be entered. Output consists of tabulated pressures, resultants, and internal forces which may be directed to a file or to the user's terminal. Graphic output includes input geometry, soil and water pressure distributions, the frame model, and shear and bending moment diagrams.

F. ADDITIONAL REMARKS

This program is available as part of the CORPS library system. Documentation is available from the Engineering Computer Program Library, US Army Engineer Waterways Experiment Station; (601) 634-2581 or (FTS) 542-2581.

PREFACE

This user's guide describes an interactive computer program, "CUFRAM," that analyzes a two-dimensional slice of a U-frame structure. The program functions in two modes, equilibrium and frame analysis. The work in developing the program and writing the user's guide was accomplished with funds provided to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., by the Civil Works Directorate of the Office, Chief of Engineers (OCE), US Army, under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were provided by members of the Locks Subgroup, U-FRAME Structures Task Group of the CASE Project. Members of the Locks Subgroup during the period of development of the program were:

Mr. Byron Bircher, Kansas City District (Task Group Chairman)
Mr. Roger Hoell, St. Louis District (Subgroup Chairman)
Mr. C. C. Hamby, Vicksburg District
Mr. Tom Quigley, St. Louis District
Mr. Tom Ruff, St. Louis District
Mr. Charles Trahan, Lower Mississippi Valley Division
Mr. Bill Price, Waterways Experiment Station

The computer program and user's guide were written by Dr. William P. Dawkins, P.E., Stillwater, Okla., under Contract No. DACW39-83-M-3000 with WES.

The work was managed and coordinated at WES by Dr. N. Radhakrishnan, Acting Chief, Information Technology Laboratory (ITL), and formerly Chief, Automation Technology Center (ATC), and Mr. Paul K. Senter, ITL, formerly Chief, Scientific and Engineering Application Division, ATC. Mr. Donald R. Dressler was the OCE point of contact. Final editing for publication of this report was provided by Mses. Gilda Miller and Deborah Shiers, editor and editorial assistant, ITL, WES.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degree (angle)	0.01745329	radians
feet	0.3048	metres
kips (force)	4.448222	kilonewtons
kips (force)-feet	1355.818	newton-metres
pounds (force)	4.448222	newtons
pounds (force) per cubic foot	0.157087	kilonewtons per cubic metre
pounds (force) per cubic inch	0.2714	megapascals per metre
pounds (force) per foot*	14.5939	newtons per metre
pounds (force) per inch	175.1268	newtons per metre
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
square inches	6.4516	square centimetres

* The same conversion factor applies for pounds (force) per linear foot (PLF).

USER'S GUIDE: COMPUTER PROGRAM FOR TWO-DIMENSIONAL ANALYSIS OF U-FRAME STRUCTURES (CUFRAM)

PART 1: INTRODUCTION

Description of Program

1. This user's guide describes a computer program "CUFRAM" for analysis of a two-dimensional (2-D) slice of a U-frame structure. The program functions in two modes. In the equilibrium mode, the program converts soil and/or water effects to surface loads on the structure, determines the resultants of all applied loads, and, for a soil-founded structure, determines the necessary base reaction distribution to equilibrate the external loads. In the frame analysis mode, a 2-D plane frame model of the structure (including piles if present) is formulated and displacements and internal forces throughout the structure (and pile forces) are determined from a linearly elastic analysis. This program provides information only regarding the response of the structure, performs no design functions, nor does it attempt to judge the quality of the structural performance.

Report Organization

2. This report is divided into the following parts:

- a. Part II: Describes the 2-D structure.
- b. Part III: Describes the external soil (backfill) and water system, the conversion of soil/water properties to structural loads, and other structure loads.
- c. Part IV: Describes the treatment of the base reaction for soil founded structures and equilibrium analysis.
- d. Part V: Describes the 2-D model formulated for frame analysis including the effects of piles for pile-founded structures.
- e. Part VI: Describes the computer program.
- f. Part VII: Presents example solutions obtained with the program.

Disclaimer

3. This program was developed using criteria furnished by the CASE task group on U-frame structures. The procedures and philosophy embodied in the program do not necessarily represent the views of the author.

4. The program has been checked within reasonable limits to ensure that the results are accurate for the assumptions and limitations of the procedures employed. In all cases it is the responsibility of the user to judge the validity of the results. The author assumes no responsibility for designs or the performance of any structure based on the results of the program.

PART II: STRUCTURE

System Description

5. The U-frame system is a three-dimensional (3-D) U-shaped structure, usually concrete, surrounded by soil backfill, founded on subsoil or piles, and subjected to a variety of soil and water (both internal and external) loads. Although an accurate assessment of the behavior of the system can be obtained only from a general 3-D analysis, such an analysis is clearly prohibitive, particularly during an iterative design process.

6. Under the following conditions, an analysis of a 2-D slice can provide relatively reliable indications of the behavior of the 3-D system:

a. When the longitudinal dimension of the system is substantially larger than the width and height of the cross section.

b. When the cross-sectional geometry of the structure and the soil and water conditions, support conditions, and other loading effects are relatively constant throughout an extended length of the system.

c. When a 2-D slice of the system, obtained by passing parallel planes perpendicular to the longitudinal axis of the system, is representative of adjacent slices and is sufficiently remote from any discontinuities in geometry and loading (i.e., the slice is in a state of plane strain).

7. The remainder of this report is based on the assumption that the above conditions exist in the 2-D representation.

Typical Cross Sections

8. The geometry of a cross section (monolith) is usually dictated by its position in the 3-D structure. Although name identifiers are frequently assigned to the various shapes, the basic types shown in Figure 1 will be designated by a type number as follows:

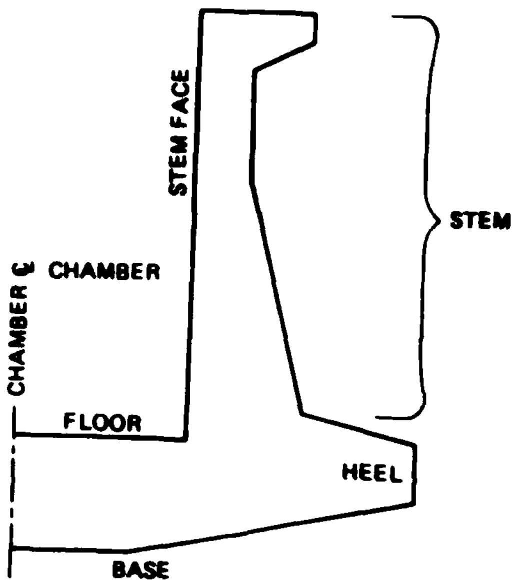
a. Type 1 monolith--no culvert or void.

b. Type 2 monolith--with culvert, no void.

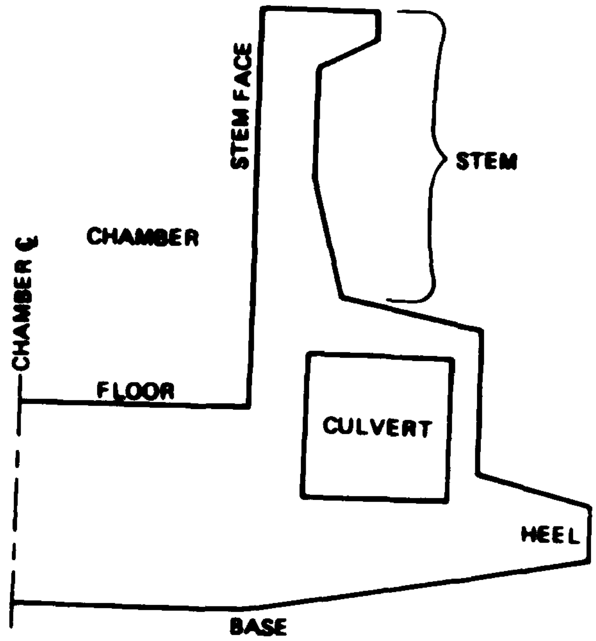
c. Type 3 monolith--both culvert and void.

9. The typical sections shown in Figure 1 are shown for the rightside*

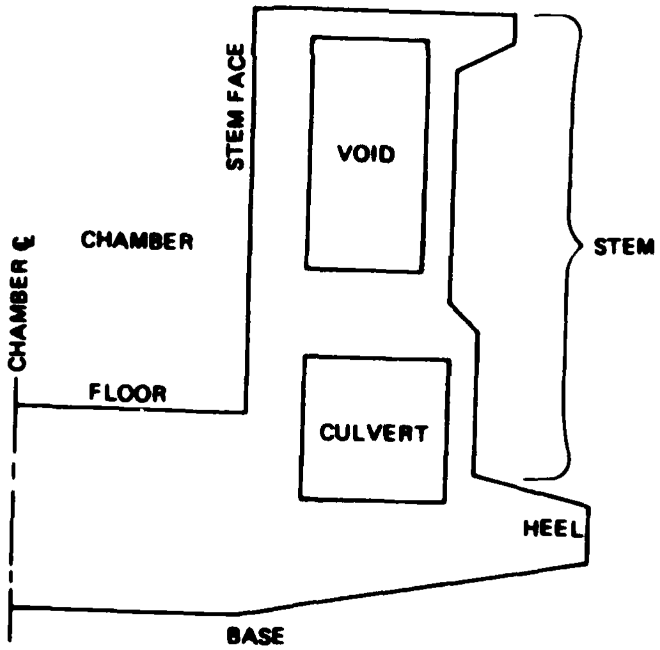
* The terms "rightside," "leftside," and "centerline" are each used in a one-word form in the text to be consistent with these terms as used in the computer program.



a. Type 1 monolith



b. Type 2 monolith



c. Type 3 monolith

Figure 1. Structural geometry

of the structure. When the structure is symmetric about the chamber centerline, only the right half need be provided and a mirror image will be created for the leftside. In an unsymmetric system, the rightside and leftside must both be described and the two sides need not be the same type. In the equilibrium mode, there are few restrictions on the geometry of the section (e.g., a section may be described as having a "VOID" but without a "CULVERT"). In the frame analysis mode, the geometry is restricted to the three types illustrated in Figure 1; limitations for this mode are described further into this report.

10. In all cases, the structure is assumed to be monolithic, mass concrete. The effects of reinforcement, construction joints, expansion joints, or any other discontinuities (cracking) in the system are not taken into account. In the frame analysis to be described later, the concrete is assumed to be linearly elastic and homogeneous.

Nomenclature, Assumptions, and Limitations

11. Listed below are the various terms applied throughout this report and the assumptions and limitations employed (Appendix A, Guide for Data Input, additional definitions and limitations):

a. Chamber centerline--vertical line midway between rightside and leftside stem faces.

b. Floor--bottom of chamber, assumed to be horizontal.

c. Base--lower boundary of structure, assumed to be horizontal to some distance from chamber centerline, then may slope up or down.

d. Stem--the essentially vertical part of the structure above the chamber floor.

e. Culvert--rectangular cavity in the vicinity of the intersection of the stem and base slab.

f. Void--rectangular cavity in the stem above the culvert.

g. Heel--protrusion of the base slab beyond the stem.

h. Elevation--vertical distance (feet) measured positive upward from any selected datum.

i. Horizontal distance--positive dimension (right or left), measured from chamber centerline unless otherwise noted.

j. Stem point--point on the outside face of the stem at which a change in geometry occurs; numbered sequentially downward with stem point 1 at the top of the stem.

k. Base point--point on the base at which a change in geometry occurs; limited to two points on each side of chamber centerline; first point defines limit of horizontal segment of base; second point may be above or below first base point; for unsymmetric structures, the first base points on each side must be at the same elevation.

l. Stem face--inner vertical boundary of stem.

PART III: BACKFILL SOIL AND WATER

Loading Effects

12. The fundamental loading effects on the structure are produced by the soil acting on the external surfaces of the stems, water in the chamber, water in the culverts (and voids), water in the backfill, and by water and/or soil acting on the base. The user has the option to provide explicit magnitudes and distributions produced by these effects or to provide the physical characteristics of the soil and water which are converted to loadings by the computer program. The procedures used to convert physical properties to structure loading are described in the next paragraphs.

Backfill Soil

13. Backfill soil, if present, produces horizontal and vertical loads on the external stem surfaces. Backfill soil pressures may be described by an input pressure distribution or by the physical properties of the soil. The backfill soil profile may be composed of one to five horizontal soil layers. Soil layer 1 is the uppermost stratum with other layers numbered sequentially downward. The last layer provided is assumed to extend ad infinitum downward. Each soil layer is characterized by these parameters:

- a. Elevation (FT) at top of the layer.
- b. Saturated soil unit weight (γ_{SAT})* (PCF)--the saturated unit weight is used by the program to obtain the effective weight of submerged soil by subtracting the weight of water from the saturated soil weight.
- c. Moist soil unit weight (γ_{MST}) (PCF)--the unit weight of the unsubmerged soil.
- d. Horizontal pressure coefficients at the top and bottom of the layer (KHT and KHB, respectively)--the coefficient is assumed to vary linearly from top to bottom of the layer, except in the last layer input where the coefficient is assumed to be constant at KHT.
- e. Shear coefficients at the top and bottom (KVT and KVB, respectively) of the layer--the coefficient is assumed to vary

---

* For convenience, symbols and abbreviations are listed in the notation (Appendix C).

linearly from top to bottom of the layer, except in the last layer input where the coefficient is assumed to be constant at KVT. (Note: The shear coefficient is intended to provide a means of approximating "down drag" effects produced by consolidation of the backfill which are not accounted for by ordinary gravity effects.)

14. A typical soil profile is shown in Figure 2a. When the ground-water elevation occurs within a soil layer, a temporary layer interface is automatically created at the ground-water elevation with soil properties evaluated as shown in Figure 2a. Horizontal and shear coefficients are obtained by linear interpolation between values at the top and bottom of the intact layer. Initially, soil properties are converted to effective vertical pressures at the top and bottom of each layer, Figure 2b. (Note: The surface surcharge, p_{vo} , may result from an applied surcharge on the ground surface or from surcharge water, see below, or both.) Horizontal and shear soil pressures are obtained from the effective vertical soil pressures by applying the horizontal and shear soil coefficients at the top and bottom of each layer, Figures 2c and 2d. Horizontal and shear soil pressures are assumed to vary linearly within a layer.

Structure Soil Loading

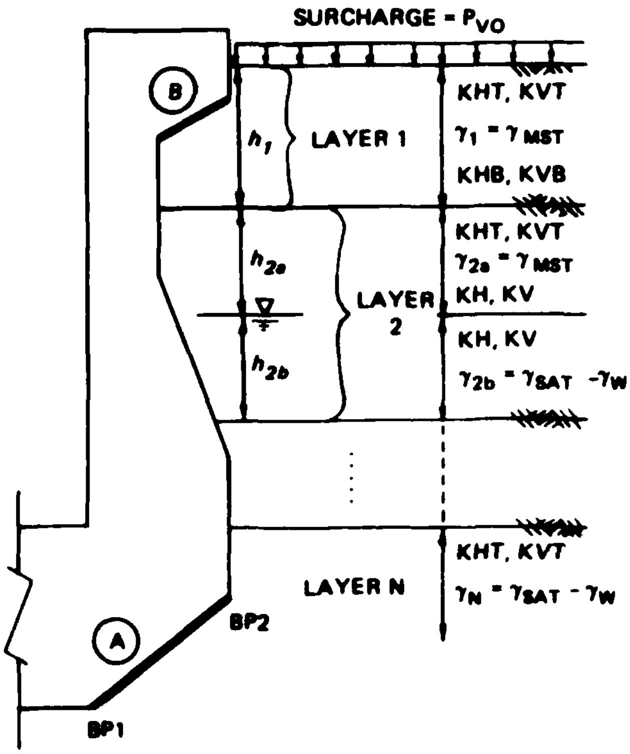
15. The resulting loading on the structure surface is obtained as illustrated in Figures 2e and 2f. The vertical, horizontal, and shear pressures acting on the vertical and horizontal surfaces of a soil element at the structure interface are converted, by Mohr's circle, to normal and tangential components on the structure surface.

Soil Force on Sloping Base

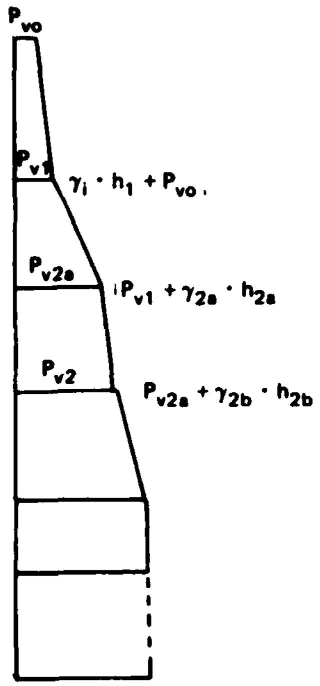
16. An upward sloping base (area A in Figure 2a) is subjected to the combined effects of backfill soil pressures and base soil reaction pressures, if present. In this case, only the horizontal component of the backfill soil pressure is applied to the sloping zone.

Tension in Backfill Soil

17. If backfill soil is in contact with the underside of an outward sloping segment of the stem surface (area B in Figure 2a), the combination of

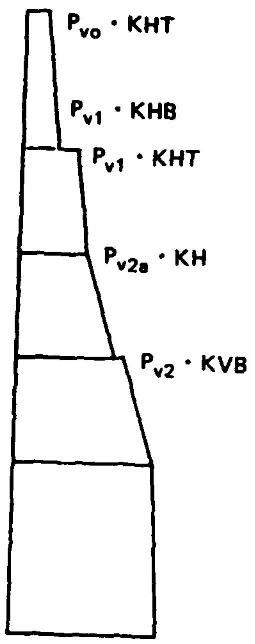


a. Backfill profile

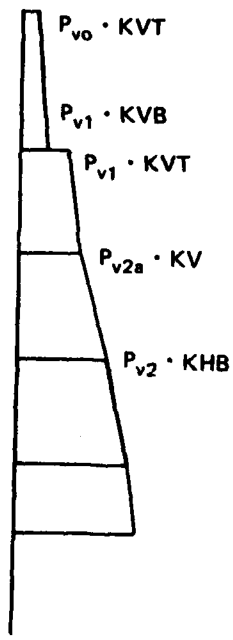


b. Vertical soil pressure

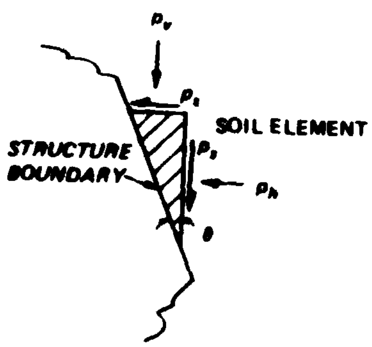
Figure 2. Backfill soil (Continued)



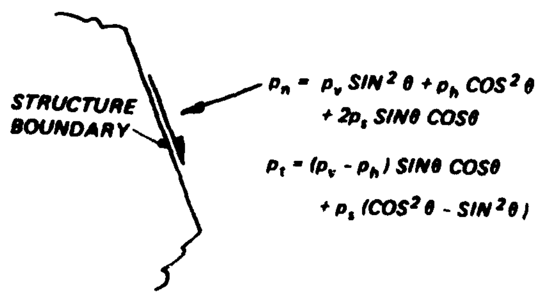
c. Horizontal soil pressure



d. Soil shear pressure



e. Soil/structure interface



f. Structure loading

Figure 2. (Concluded)

backfill soil pressures may result in a tension normal component. When this is encountered, the normal component is set to zero.

Water

18. Water loads may be applied to all surfaces of the structure, both internal and external. The user may select a variety of water loading effects as described below.

Internal water

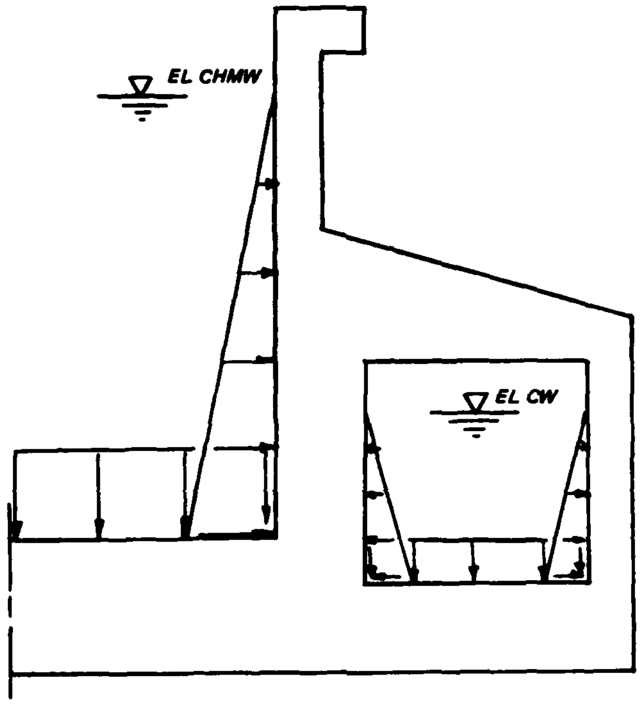
19. Internal water is defined to be any water producing loads on the chamber floor, the interior stem face, the interior surfaces of the culvert, and possibly on the interior surfaces of the void. Water effects are specified on the chamber floor and interior stem faces by an elevation of chamber water. The resulting load on the structure is a downward pressure on the chamber floor and a triangular horizontal pressure on the interior stem face, Figure 3a.

20. The effective water elevation in the culverts (rightside, leftside, or both) is assumed to be independent of the chamber water. When the elevation of water in the culvert is below the culvert roof, water loads are produced on the interior culvert surfaces as shown in Figure 3a. If the elevation of water in the culvert is specified above the culvert roof, water loads are produced on all surfaces of the culvert (Figure 3b).

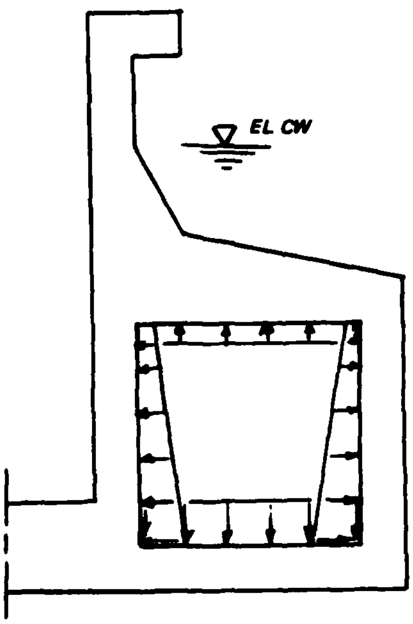
21. Culvert water may also produce loads on the interior walls of a void if the void floor and culvert roof are at the same elevation (Figure 3c). A void without a culvert or a void with its floor above the culvert roof is assumed to be dry.

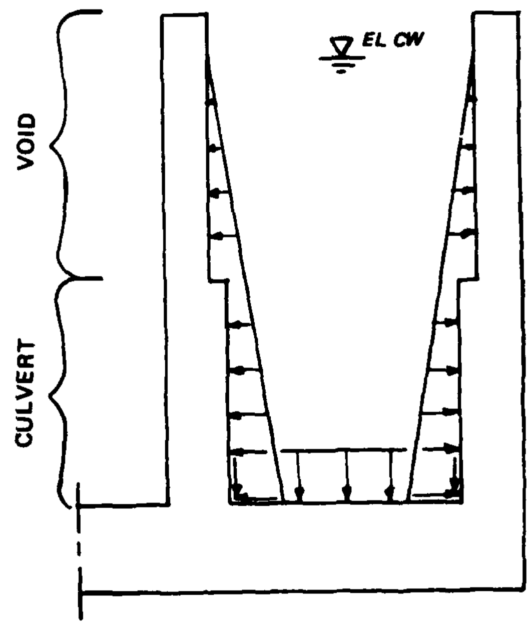
External water

22. External water (water acting on the external stem surfaces) not only produces hydrostatic loads directly on the surface of the structure but may also affect backfill soil loads. The user may elect to provide external water effects in the form of a pressure distribution or by specifying the water elevations. An input pressure distribution is assumed to be the hydrostatic pressure only acting on the structure surface and has no effect on backfill soil. Conversely, if a backfill soil pressure distribution has been provided, this distribution is not altered by the presence of external water.



a. Culvert water elevation below top of culvert





b. Culvert water elevation above top of culvert

c. Culvert and void connected

Figure 3. Internal water

Ground water

23. Ground water is defined to be that part of the external water which reduces the effective weight of backfill soil in addition to producing hydrostatic pressures on the structure surface. The effective weight of any submerged soil is automatically determined by the program.

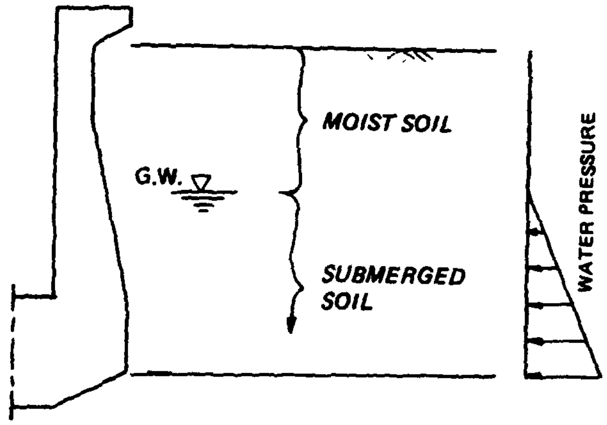
Surcharge water

24. An additional external water loading may be imposed in the form of surcharge water acting on the structure above the backfill soil surface. When surcharge water is present, the backfill soil surface is assumed to be covered by an impermeable membrane. Surcharge water produces hydrostatic pressures on the external surfaces of the structure above the soil surface. In addition to this, it produces a vertical surcharge load on the soil surface which increases soil effective pressures (hence, soil horizontal and shear pressures) below the soil surface. Various combinations of ground and surcharge water effects are shown in Figure 4. Note that surcharge water does not affect submergence conditions in the backfill soil (Figure 4b). If both ground water and surcharge water are present and the ground-water elevation is above the soil surface, the resulting pressure distribution will be as shown in Figure 4c. Only surcharge water pressures are applied to the structure surfaces above the soil surface. Likewise, the surcharge load on the soil surface is the result of the surcharge water only. Below the soil surface, hydrostatic pressures on the structure surface and submergence effects are produced by ground water only. This combination will produce a discontinuity in hydrostatic pressures at the soil surface.

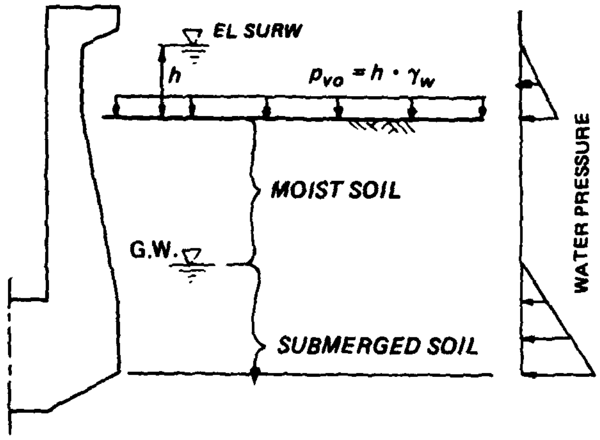
25. In the case of an upward sloping base, as illustrated in Figure 2a, ground-water hydrostatic pressures on the structure are terminated at the elevation of base point 2. Any water effects below this elevation are assumed to be the result of uplift water.

Uplift water

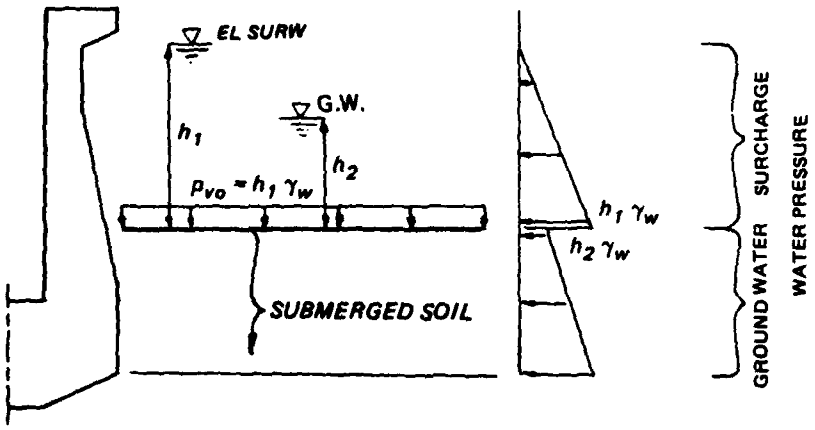
26. Uplift water effects on the base of the structure may be described by a pressure distribution or by specifying uplift water elevations on each side of the structure. When uplift water elevations are provided, it is assumed that the uplift head varies linearly across the structure between the rightside and leftside elevations prescribed. Uplift water is assumed to be independent of ground water.



a. Ground water without surcharge water



b. Surcharge water and ground water



c. Ground water above soil surface

Figure 4. External water

Additional Loads

27. In addition to the soil and water loads described above, the user may specify any combination of concentrated or distributed loads to the structure surface, i.e., to the chamber floor, the interior stem face, the exterior stem face, the top of the stem, or the base.

Resultants of Loads

28. All distributed loads (soil, water, and additional loads) are combined into net normal and tangential pressures on the structure surface, Figure 2f. Three resultants of all loads are determined for the rightside and leftside (if necessary) of the structure. These resultants are: the sum of all horizontal loads, the sum of all vertical loads, and the sum of moments of all loads about the centerline of the chamber floor. The rightside and leftside resultants are then combined into net resultants for the entire structure. In the case of a symmetric system, only the net vertical resultant at this stage will be nonzero.

PART IV: BASE REACTION FOR SOIL-SUPPORTED SYSTEMS

29. In the case of a pile-supported structure, any unbalanced resultants (horizontal, vertical, or moment) will be equilibrated by forces developed in the piles. For soil-supported systems, unbalanced resultants are equilibrated by soil pressures acting on the base. A combination of soil and pile supports is not directly accommodated. However, an approximation of combined supports may be obtained by specifying a pile-supported structure and by applying additional distributed loads to simulate soil support. Determination of base reaction pressures for soil-supported systems is described below.

Symmetric Systems

30. In a symmetric system, only the net vertical resultant of all loads will be nonzero. This resultant is equilibrated by vertical soil pressures acting on the horizontal projection of the entire structure base (i.e., from base point 2 on the leftside to base point 2 on the rightside). Equilibrium may be established automatically with one of the prescribed base pressure distributions described below or by a user-supplied distribution to be discussed subsequently.

Automatic base pressure calculations (symmetric system)

31. One of three prescribed base pressure distributions may be selected from those shown in Figure 5. The procedures used to evaluate the pressures associated with each distribution are given in the next three paragraphs.

Uniform distribution (symmetric system)

32. The base reaction pressure is uniform over the entire base:

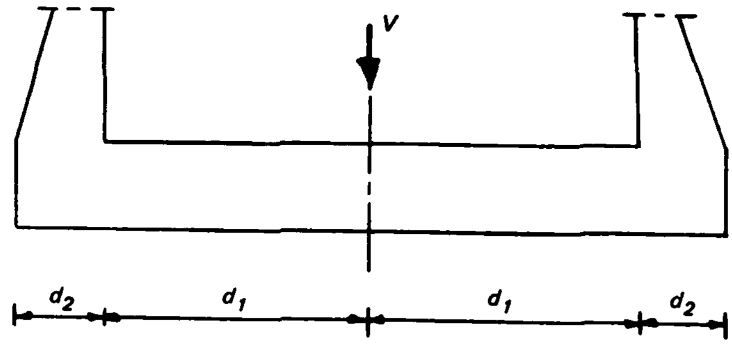
$$p_u = \frac{V}{2d_1 + 2d_2}$$

where

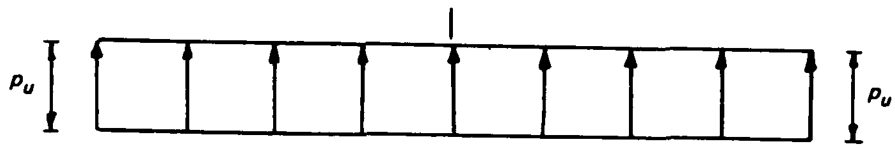
p_u = uniform pressure

V = net vertical reaction of applied loads

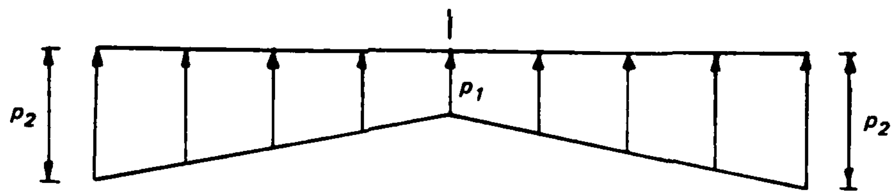
d_1, d_2 = dimensions shown in Figure 5a



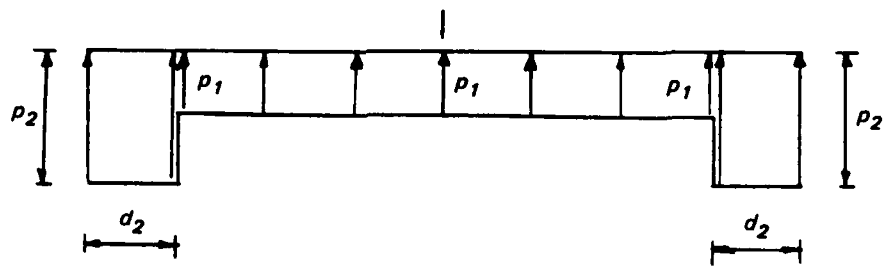
a. Symmetric system



b. Uniform



c. Trapezoidal



d. Rectangular

Figure 5. Automatic base reaction distributions for symmetric systems

Trapezoidal distribution (symmetric system)

33. The base reaction pressure varies linearly from the chamber centerline to the extreme edge of the base:

$$p_1 = R \cdot p_u$$

$$p_2 = \frac{V}{d_1 + d_2} - p_1$$

where

p_1 = base pressure at the chamber centerline

R = factor prescribed by the user $(0 < R < 2)$

p_u = uniform base pressure from paragraph 32

p_2 = base pressure at extreme edge of the base

Rectangular distribution (symmetric system)

34. The base pressure distribution is composed of three regions of constant pressure: p_l under the chamber floor; p_2 under the regions from the interior stem faces to the extreme edges of the base:

$$p_1 = R \cdot p_u$$

where

p_1 = uniform pressure under the chamber floor

R = factor prescribed by the user $[0 < R < (d_1 + d_2)/2d_1]$

p_u = uniform pressure from paragraph 32

p_2 = $[(V - 2p_1d_1)/2d_2]$

= uniform pressure from interior stem face to extreme edge of base

User-Specified Base Pressure Distribution

35. As an alternative to the automatically generated distributions just described, the user may prescribe any symmetric distribution desired. Because the net resultant of vertical loads will usually not be known initially, the user-supplied distribution may not equilibrate the vertical resultant; the

user may elect to have the program scale the input distribution to establish equilibrium, i.e.,

$$p_{actual} = p_{input} \cdot \frac{V}{V_u}$$

where

p_{actual} = adjusted base pressure

p_{input} = user-specified pressure

V = net resultant of applied vertical loads

V_u = vertical resultant of user-specified base pressure distribution

Unsymmetric Systems

36. In an unsymmetric system, any or all of the net resultants of applied loads may be nonzero. The procedures available to establish equilibrium of unsymmetric systems are described below.

Unbalanced horizontal resultant

37. The unbalanced horizontal resultant on the 2-D slice would be equilibrated in the 3-D structure by friction along the base of the structure, by horizontal shear forces transmitted through the structure to adjacent slices, or a combination of the two. The user has several options for establishing horizontal equilibrium.

a. Base friction. Horizontal equilibrium is achieved by applying horizontal friction forces along the actual horizontal zone of the base (i.e., from base point 1 on the leftside to base point 1 on the rightside).

b. Base shear. Horizontal equilibrium is achieved by applying horizontal shear forces along the centerline of the base slab under the chamber floor (i.e., between interior stem faces).

c. Combination. A combination of base friction and base shear is not directly accommodated by the program. However, the user may use the additional load capability described previously to apply horizontal surface loads simulating shear or friction or both, and direct any remaining horizontal imbalance to shear or friction, as above.

Unbalanced vertical and moment resultants

38. Unbalanced vertical and moment resultants in unsymmetric systems

are coupled and must be equilibrated simultaneously. Equilibrium of vertical and moment resultants is established as follows:

a. The net resultants of applied loads, H, V, M_1 (M_1 = moment resultant about the chamber floor centerline), are determined.

b. Horizontal equilibrium is satisfied as described above.

c. A new moment resultant, M_2, which includes the moment of base horizontal shear or friction is determined for a point on the base at the chamber floor centerline. (Note that for an unsymmetric structure, this point will not be at the midpoint between the extreme edges of the base.)

39. An unsymmetric system and the final unbalanced vertical and moment, M_2 resultants are shown in Figure 6a. The options available to the user to establish equilibrium depend on whether one of the automatic distributions for base pressure has been prescribed or whether the user has provided his own base pressure distribution.

Equilibrium with Automatic Base Pressure Distributions

40. When one of the three automated base pressure distributions has been selected, the following steps are used to establish vertical or moment equilibrium.

Vertical equilibrium

41. The vertical resultant is equilibrated by one of the three initial distributions shown in Figures 6b, c, and d:

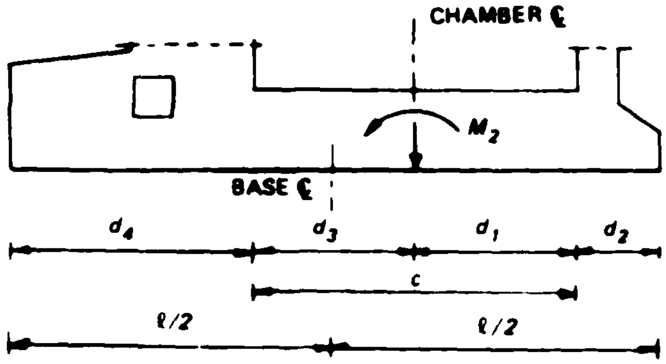
a. Uniform

$$p_u = \frac{V}{\ell}$$

b. Trapezoidal

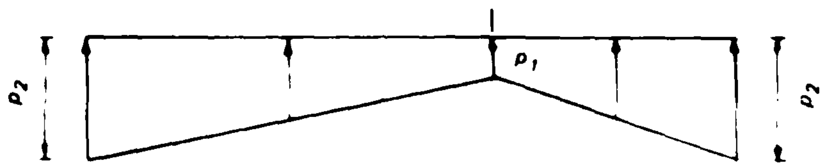
$$p_1 = R \cdot p_u$$

$$p_2 = \frac{2V}{\ell} - p_1$$

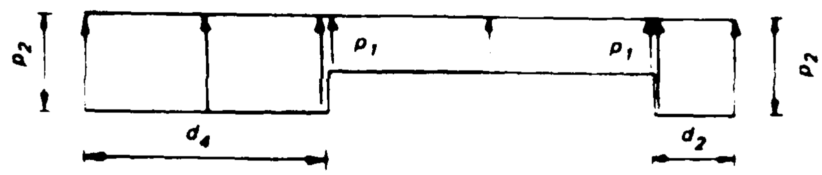


a. Unsymmetric system

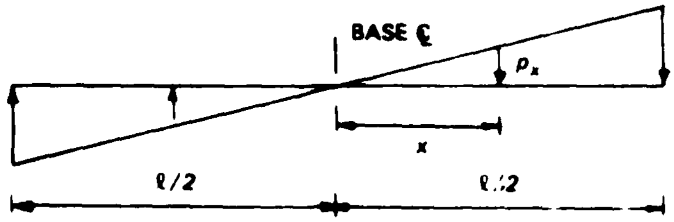
b. Uniform, initial



c. Trapezoidal, initial



d. Rectangular, initial



e. Moment contribution

Figure 6. Automatic base pressure distributions for unsymmetric systems

c. Rectangular

$$p_1 = R \cdot p_u$$

$$p_2 = \frac{V - p_1 c}{d_2 + d_4}$$

Moment equilibrium

42. Because of the nonsymmetry of the above initial distributions, the net vertical resultant and the resultant of the initial distribution, while equal in magnitude, will not be colinear. The couple formed by the two vertical resultants is added to the moment resultant, M_2 , to form a third unbalanced moment resultant, M_3 , (i.e., unbalanced moment about the base centerline). Equilibrium of this resultant is established by adding a linear pressure distribution to the initial base pressure distribution, Figure 6e:

$$p_x = -12\left(\frac{M_3 x}{\ell^3}\right)$$

where

p_x = pressure due to unbalanced moment

M_3 = unbalanced moment

x = distance from base centerline, positive to the right

ℓ = width of the structure base

Equilibrium with user-supplied base pressure distribution

43. Two options are available when the user-supplied base pressure distribution does not equilibrate the net vertical resultant, V , and the moment resultant, M_2 .

Adjustment of User-Supplied Distribution

44. Vertical equilibrium is established by augmenting the input pressure at each point according to

$$P_{actual} = P_{input} \cdot \frac{V}{V_u}$$

where

P_{actual} = adjusted base pressure

P_{input} = user-specified pressure

V = net resultant of applied vertical loads

V_u = vertical resultant of user-specified base pressure distribution

45. Again, the couple due to the vertical resultant, V, and the resultant of the augmented pressure, V_u, is added to the net moment resultant, M_2, to form a final unbalanced moment resultant, M_3. This final resultant is equilibrated by adding a linear pressure distribution (paragraph 45) to the user supplied distribution.

Vertical Structural Shear

46. Any portion of the vertical and/or moment resultant not equilibrated by the user-supplied base pressure distribution may be assumed to be resisted by vertical shear forces in the structure stems. The resultants of these structure shear forces are established according to

$$V_R = \frac{V^*d_L - M^*}{d_L - d_R}$$

$$V_l = V^* - V_R$$

where

V_R, V_L = resultants of vertical stem shear forces

V^*, M^* = vertical and moment unbalances remaining after combining resultants of applied loads and resultants of user-supplied base reaction

d_L, d_R = distances from chamber centerline to line of action of leftside and rightside vertical shear forces. In the equilibrium mode, d_L (d_R) is the average thickness of the leftside (rightside) stem plus half of the chamber width. In the frame analysis mode, d_L, d_R are the distances from the chamber

centerline to the centroid of the inside rigid block (paragraph 62).

Negative Base Pressures

47. In severely unsymmetric systems, combination of the linear pressure distribution due to moment unbalance with the initial automatic or user-supplied base pressure distribution may result in negative (i.e., tension) base pressures. When this condition is encountered, the user is notified by the program and execution is terminated.

Equilibrium Mode

48. Evaluation of soil, water, and base reaction pressures, and net unbalanced resultants (for pile-supported structures) constitutes the extent of computations performed in the equilibrium mode. The user should exercise the program in this mode to verify structural loadings and resultants before attempting a complete frame analysis. It should be noted that an equilibrium analysis may be performed for a variety of structures which are not accommodated in the frame analysis mode.

PART V: FRAME ANALYSIS

General Overview

49. The equilibrium phase of the analysis described in paragraph 48 determines the distribution of loads around the periphery of the structure. When a frame analysis is specified, relative displacements and axial, shear, and bending moment forces are evaluated throughout the structure using a 2-D plane frame model of the structure.

Restrictions on Structure Geometry

50. There are few limitations on the structure geometry when the program is exercised in the equilibrium mode. In order to preform a frame analysis, the following limitations are imposed. (In the following discussion, the term "monolith" refers to the shape of the structure on each side of the chamber centerline. A structure may have different types of monoliths on each side. However, at the chamber centerline, the thickness of the base slab must be the same for the two halves.)

51. There are six basic monoliths permitted for frame analysis: type 1, type 2, and four variations of type 3, subsequently designated as types 31 through 34. The requirements on geometry for each of these types are discussed below. In the following descriptions, reference is made to "rigid blocks" at various locations in the structure. This term and the effects of rigid blocks will be discussed later.

Type 1 Monolith

52. A type 1 monolith, Figure 7, has neither a culvert nor a void in the stem. Six stem points, S1 through S6, are required with the following limitations on horizontal distance from the stem face (D_i) and elevation (E_i) for the i^{th} stem point:

<u>a</u>. $E_1 > E_f$, $D_1 > 0$

<u>b</u>. $E_2 < E_1$, $D_2 = D_1$

<u>c</u>. $E_3 \le E_2$, $D_3 \le D_2$

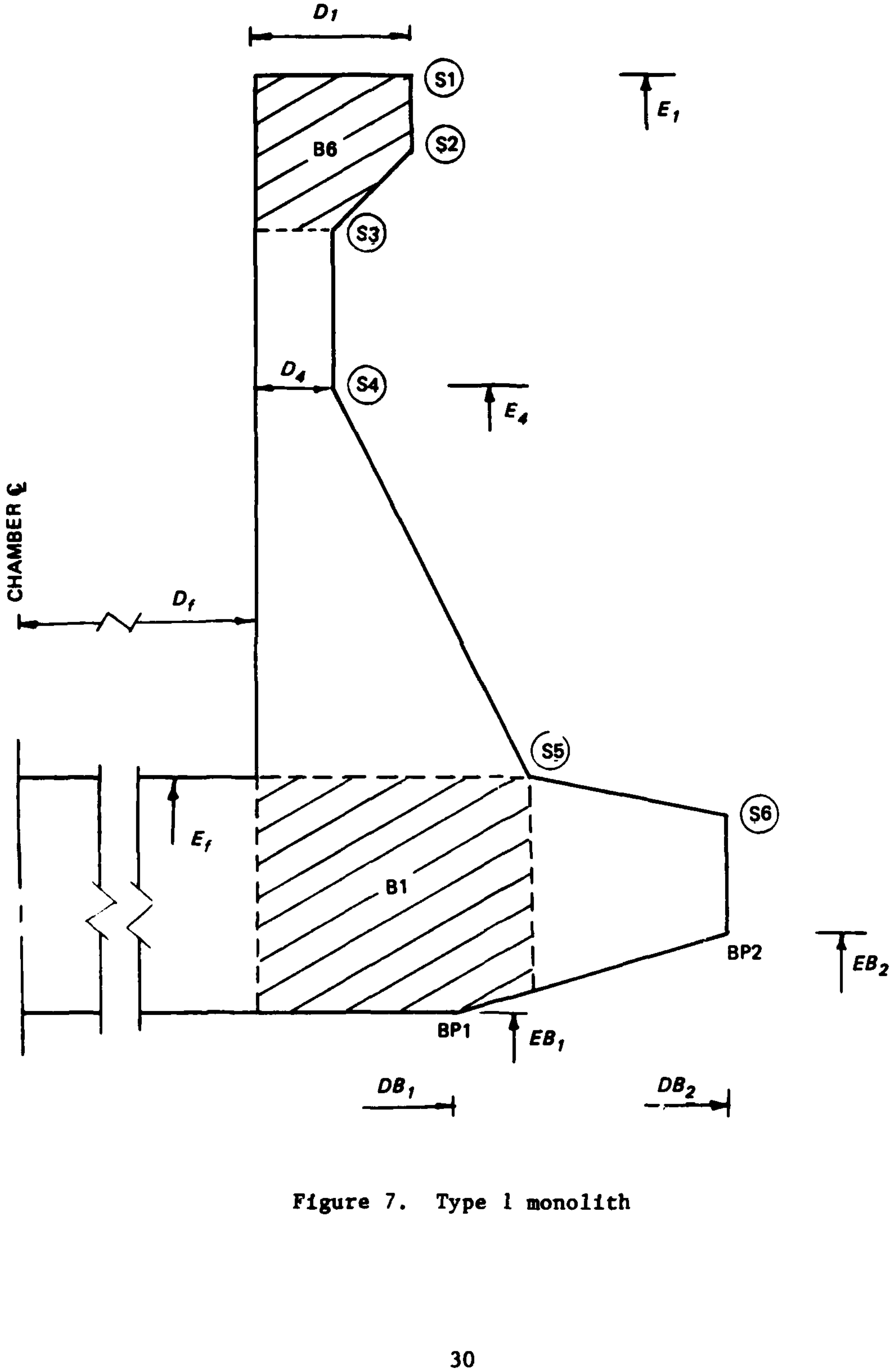


Figure 7. Type 1 monolith

(Stem points S1 through S3 define the top rigid block B6.)

d. $E_3 > E_4 > E_5$, $D_4 > 0$

e. $E_5 \le E_f$, $D_5 > 0$

(Stem point S5 defines one limit of rigid block B1.)

f. $E_6 \le E_5$, $D_6 \ge D_5$

(If $E_6 = E_5$ and $D_6 = D_5$, heel is omitted.)

g. If only one base point provided,

$E_{B1} < E_6$, $D_{B1} = D_f + D_6$

h. If two base points provided,

$E_{B2} < E_6$, $D_{B2} = D_f + D_6$ and

$D_{B1} \le D_f + D_5$

Type 2 Monolith--Standard Case

53. A type 2 monolith, Figure 8, has a culvert in the stem but no void. Eight stem points are required and five (B1, B2, B3, B4, B6) rigid blocks are associated with the standard case. The following limitations are imposed:

a. The bottom of the culvert must be at or below the elevation of the chamber floor.

b. The top of the culvert must be above the elevation of the chamber floor.

c. $E_1 > E_f$, $D_1 > 0$

d. $E_2 < E_1$, $D_2 = D_1$

e. $E_3 \le E_2$, $D_3 \le D_2$

f. $E_3 > E_4 > E_5$, $D_4 > 0$

(Stem points S1, S2, S3 define block B6.)

g. E_5 above top of culvert, $D_5 > 0$

(S5 defines one limit of block B3.)

h. $E_6 \le E_5$, $D_6 \ge D_5$, stem point S6 must be above and outside of top, outside corner of culvert

i. $E_7 < E_6$, $D_7 > 0$

(S7 defines one limit of block B1.)

j. $E_8 \le E_7$, $D_8 \ge D_7$

(If $E_8 = E_7$ and $D_8 = D_7$, heel is omitted.)

k. If one base point provided,

$E_{B1} < E_8$, $D_{B1} = D_f + D_8$

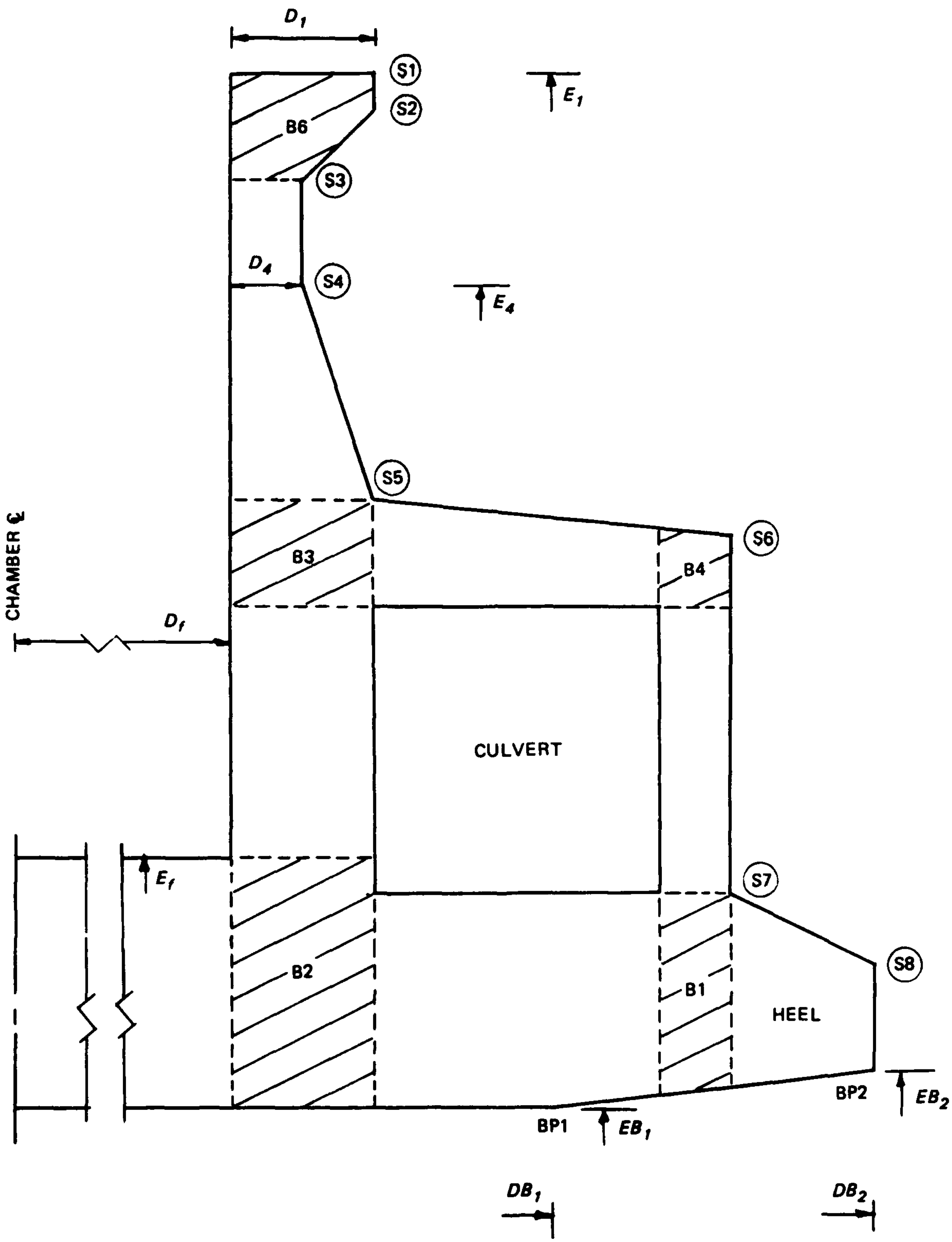


Figure 8. Type 2 monolith, standard case

$\underline{1}$. If two base points provided,

$E_{B2} < E_8$, $D_{B2} = D_f + D_8$

$D_{B1} \leq D_f + D_7$

54. In some special cases of the type 2 monolith, it may be desired that the entire culvert roof be treated as a rigid block, i.e., blocks B3 and B4 merge into a single rigid block. To impose this case, Figure 9, stem points S5 and S6 must coincide ($E_5 = E_6$, $D_5 = D_6$). All other restrictions of the standard type 2 monolith apply.

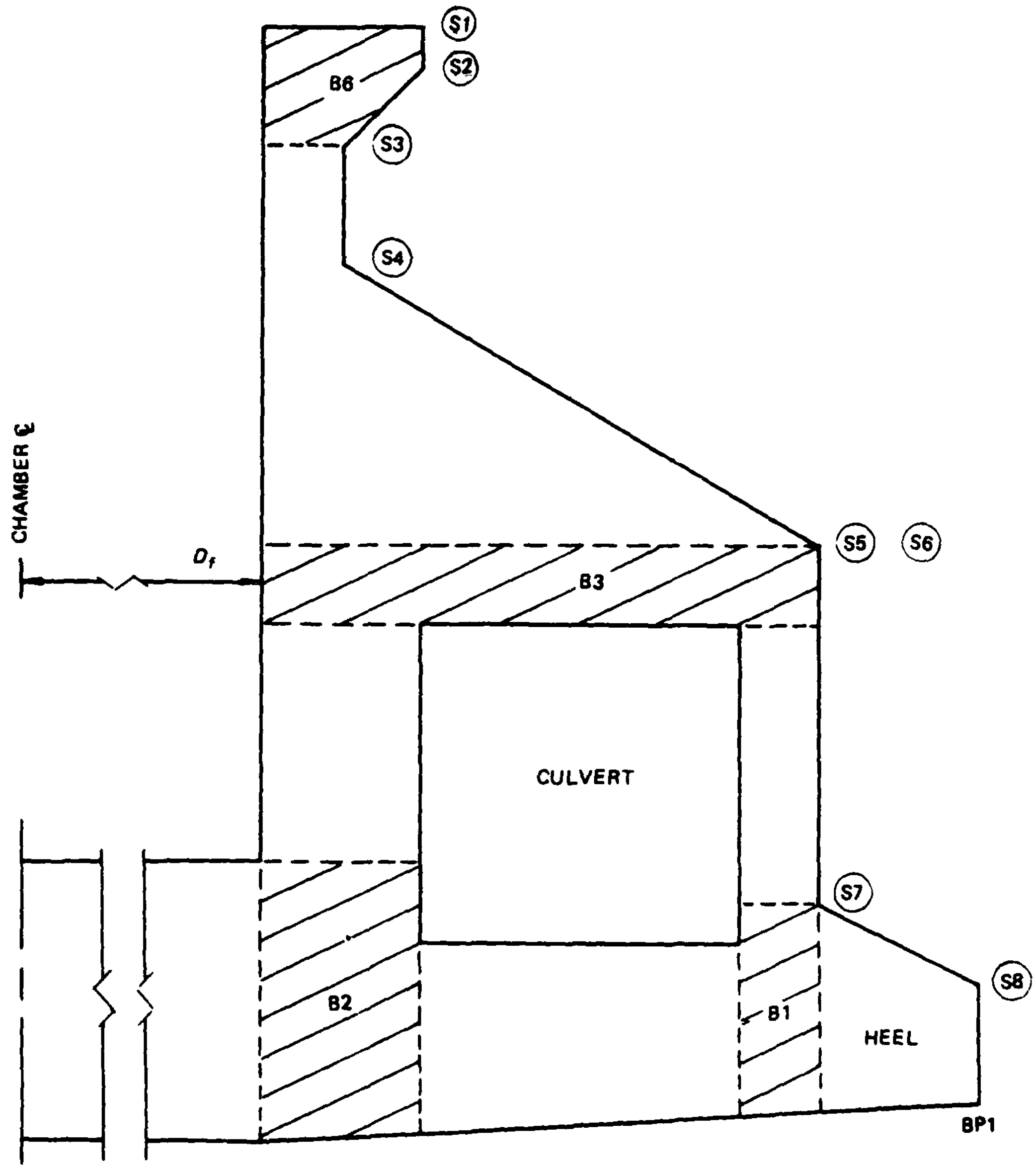


Figure 9. Type 2 monolith, special case

Type 3 Monolith--Variations

55. A type 3 monolith must have both a culvert and a void in the stem with six associated rigid blocks. Depending on the dimensions of the culvert and void, four distinct variations (types 31, 32, 33, and 34) of type 3 monoliths may arise. In all cases, the floor of the culvert must be at or below the elevation of the chamber floor and the top of the culvert must be above the chamber floor.

Type 31 monolith

56. The culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is closed ($E_1 > E_v + H_v$). Seven stem points are required, as shown in Figure 10.

a. $E_1 > E_f$, $E_1 > E_v + H_v$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_2 \geq E_3 > E_v$, $D_2 \geq D_3 > D_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_4 < E_3$, $D_4 > D_v$

e. $E_4 \geq E_5 \geq E_c + H_c$, $D_5 > D_c$

f. $E_5 > E_6 < E_c + H_c$, $D_6 > D_c$

(Stem point S6 defines block B1.)

g. $E_7 \leq E_6$, $D_7 \geq D_6$

(If S6 and S7 coincide, heel is omitted.)

h. If only one base point provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$

$D_{B1} \leq D_f + D_7$

Type 32 monolith

57. The culvert and void are connected (i.e., $E_v = E_c + H_c$) and the top of the void is closed (i.e., $E_1 > E_v + H_v$). A type 32 monolith has four rigid blocks (B1, B2, B5, B6). A discussion of the effect of discontinuities in the culvert and void walls at their intersections will be discussed (i.e., blocks B3 and B4 of the type 31 monolith degenerate to lines). Five stem points are required, as shown in Figure 11.

a. $E_1 > E_v + H_v$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

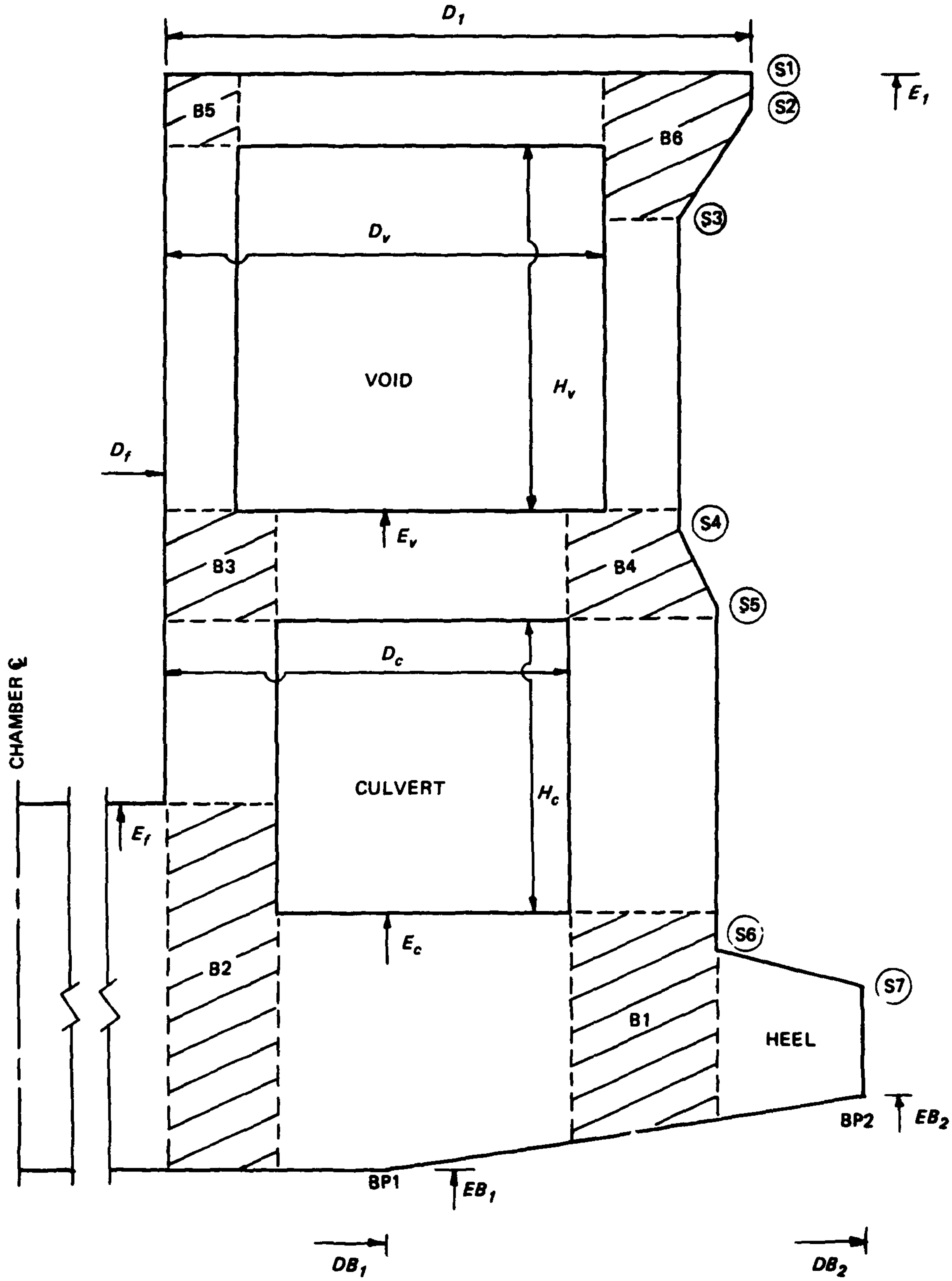


Figure 10. Type 31 monolith

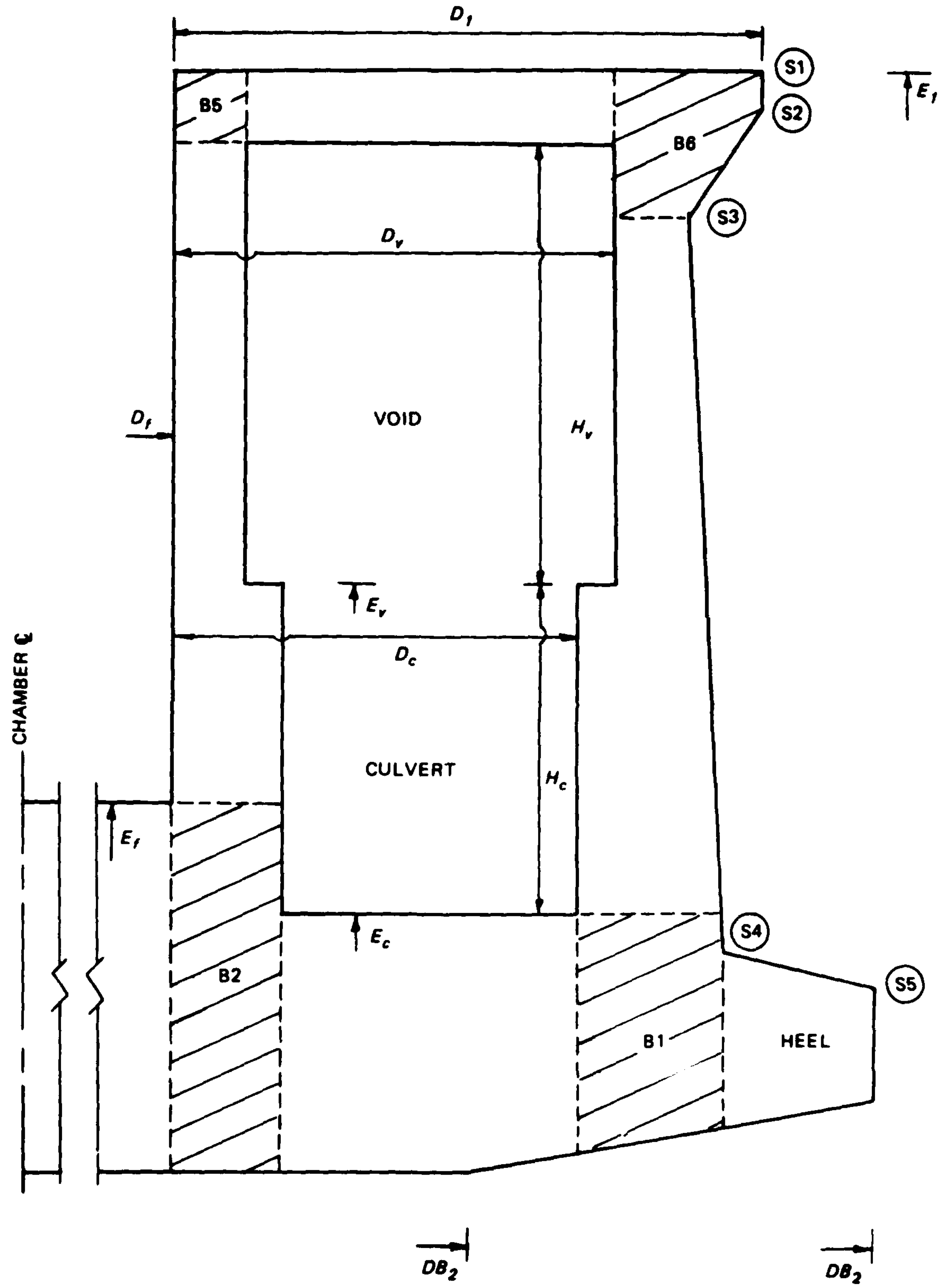


Figure 11. Type 32 monolith

c. $E_3 \leq E_2$, $D_2 \geq D_3 > D_v$

(Stem points S1, S2, S3 define block B6.)

d. $E_4 < E_v$, $D_4 > D_c$

e. $E_5 \leq E_4$, $D_5 \geq D_4$

(If S4 and S5 coincide, heel is omitted.)

f. If only one base point provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$

$D_{B1} \leq D_f + D_4$

Type 33 monolith

58. The culvert and void are separated (i.e., $E_v > E_c + H_c$) and the top of the void is open (i.e., $E_1 = E_v + H_v$). A type 33 monolith has five rigid blocks (B1, B2, B3, B4, B6). Block B5 of the type 31 monolith is absent. Seven stem points are required, as seen in Figure 12.

a. $E_1 = E_v + H_v$, $E_1 > E_f$, $D_1 > D_v$

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_v < E_3 \leq E_4$, $D_v < D_3 \leq D_2$

(Stem points S1, S2, S3 define block B6.)

d. $E_c + H_c < E_4 < E_v$, $D_4 > D_v$

e. $E_4 \geq E_5 \geq E_c + H_c$, $D_5 > D_c$

(Stem point S6 defines block B1.)

f. $E_6 < E_5$, $D_6 > D_c$

g. $E_7 \leq E_6$, $D_7 \geq D_6$

(If S6 and S7 coincide, heel is omitted.)

h. If only one base point provided,

$E_{B1} < E_7$, $D_{B1} = D_f + D_7$

i. If two base points provided,

$E_{B2} < E_7$, $D_{B2} = D_f + D_7$

$D_{B1} \leq D_f + D_6$

Type 34 monolith

59. The culvert and void are connected (i.e., $E_v = E_c + H_c$) and the void top is open (i.e., $E_1 = E_v + H_v$). A type 34 monolith has three rigid blocks (B1, B2, B6). Blocks B3 and B4 degenerate to lines; block B5 is absent. Figure 13 shows the five stem points that are required.

a. $E_1 = E_v + H_v$, $E_1 > E_f$, $D_1 > D_v$

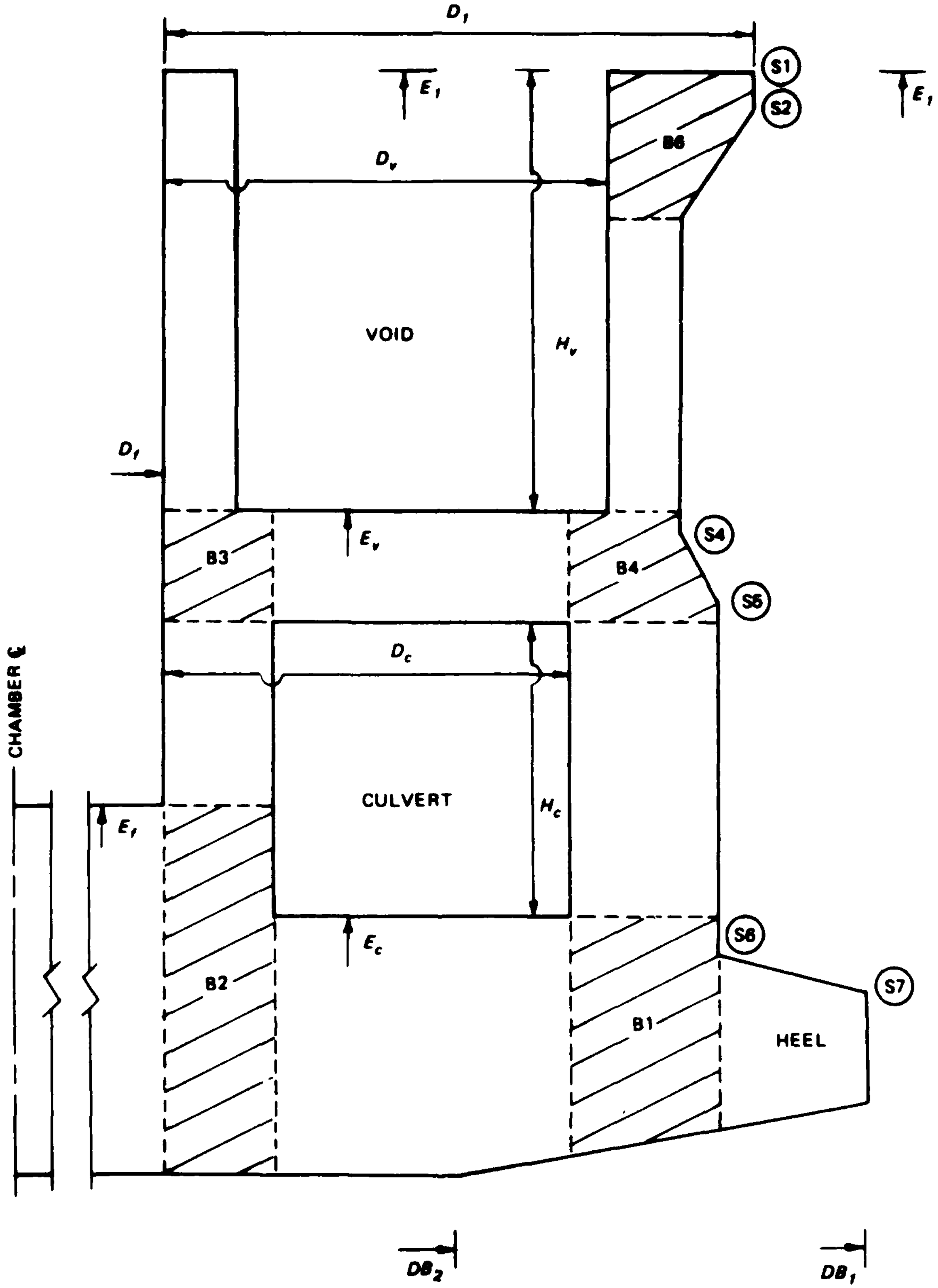


Figure 12. Type 33 monolith

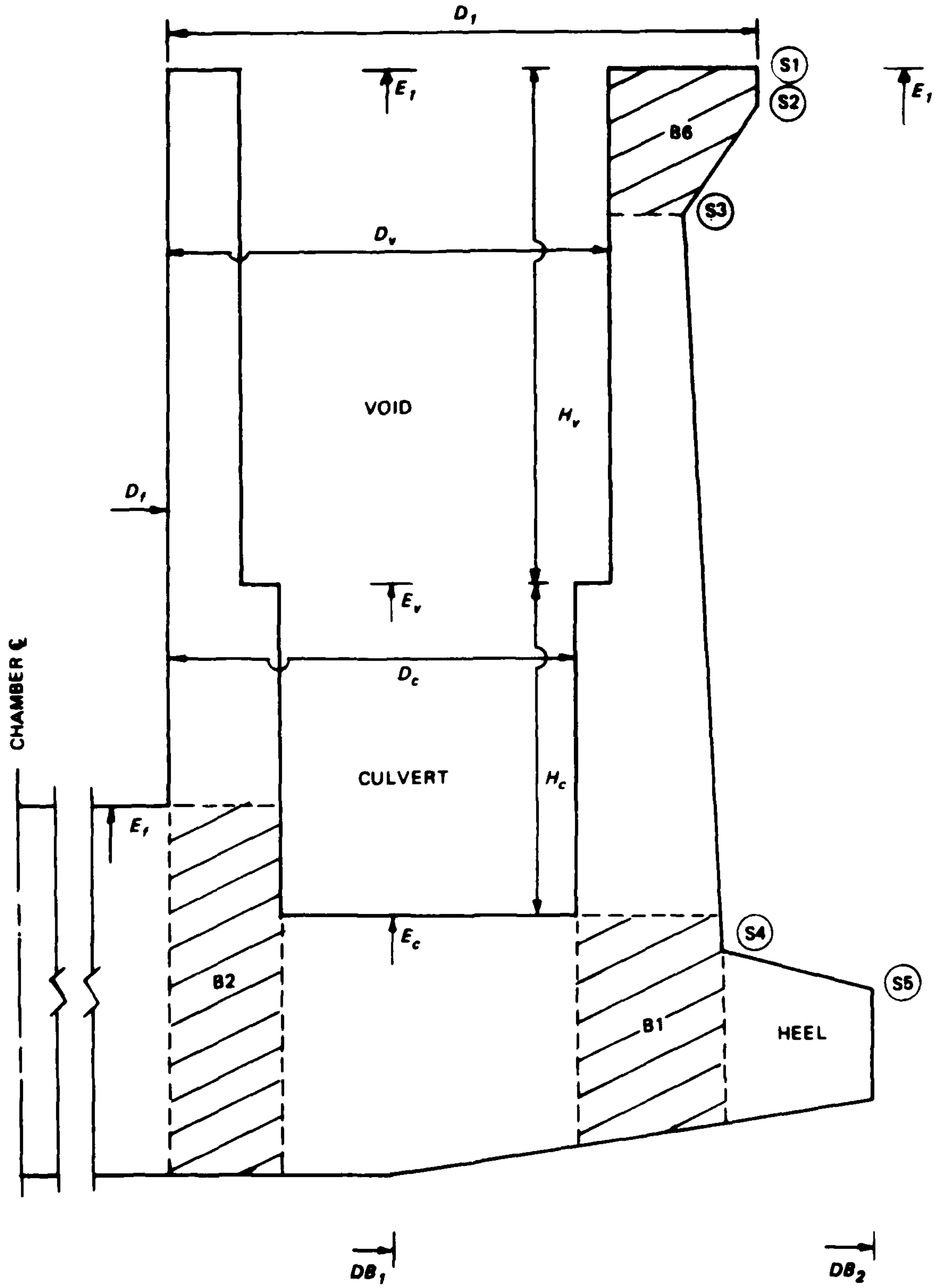


Figure 13. Type 34 monolith

b. $E_2 < E_1$, $D_2 = D_1$

c. $E_v < E_3 \leq E_2$, $D_v < D_3 \leq D_2$

(Stem points S1, S2, S3 define block B6.)

d. $E_4 < E_c + H_c$, $D_4 > D_c$

(Stem point S4 defines block B1.)

e. $E_5 \leq E_4$, $D_5 \geq D_4$

(If S4 and S5 coincide, heel is omitted.)

f. If only one base point provided,

$E_{B1} < E_5$, $D_{B1} = D_f + D_5$

g. If two base points provided,

$E_{B2} < E_5$, $D_{B2} = D_f + D_5$

$D_{B1} \leq D_f + D_4$

Caution

60. Myriad checks of user input data are performed by the computer program to assure compliance of the data with the assumptions and restrictions described above. Because the variations of structural geometry and loading are innumerable, it is possible that some descriptions are accepted by the program for which strict compliance has not been met. It is the responsibility of the user to verify that any results produced by the program are appropriate for his system.

Frame Model

61. Structural analysis of the U-frame is based on the assumption that the various slabs, walls, etc. of the structure interact as elements (members) of a 2-D plane frame. Establishment of a plane frame representation of the structure requires designation of parts of the structure as flexible "members" connected at their ends to joints. While some regions of the structure may lend themselves to treatment as flexible members (i.e., beam bending elements), there exist significant zones of mass concrete which cannot be assigned bending characteristics. These zones, alluded to previously, have been assumed to be rigid. The location and extent of these rigid blocks, their effect on the members connected to the blocks, the member characteristics, and locations of joints are described below.

Rigid Blocks

62. Depending on the type of monolith, from two to six rigid blocks are defined. The size and shape of the rigid blocks are determined by the relative positions of the various input dimensions of the structure. The geometry of each rigid block is prescribed by elevations and distances from the chamber centerline at six points around the periphery of each block as follows.

Block B1--type 1 monolith

63. In a type 1 monolith, block B1 is at the intersection of the base slab and stem (and heel, if present). The locations of the six points on the block for several example combinations of structural dimensions are shown in Figure 14 by the circled numbers. Any corner of the block which does not coincide with the location of a stem point or base point is obtained by linear interpolation between the two bounding input points.

Block B1--type 2 or type 3 monolith

64. Block B1 in type 2 or any of the type 3 monoliths occupies the intersection of the base slab and the outside culvert wall (and heel, if present). Examples of block B1 geometries for a type 2 monolith are shown in Figure 15. Identical geometries apply to any of the type 3 monoliths, except that the last two stem points are: S6 and S7 for types 31 and 33; and S4 and S5 for types 32 and 34.

Block B2--type 2 or type 3 monolith

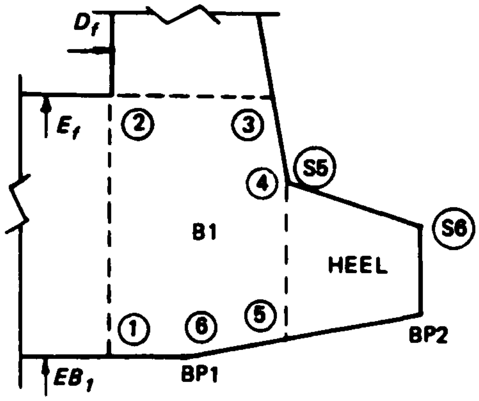
65. Block B2, types 2 and 3 monoliths, occupies the intersection of the base slab with the interior culvert wall. Example geometries of block B2 are shown in Figure 16.

Block B3--type 2 monolith

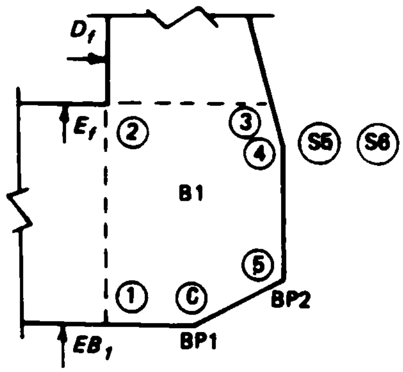
66. For a standard type 2 monolith, block B3 occupies the intersection of the interior culvert wall, the culvert roof slab, and the stem above the culvert. Example geometries for this case are shown in Figure 17. When stem points S5 and S6 coincide, block B3 occupies a rectangular area bounded by the stem face, the top of the culvert, and the elevation and distance to stem point S5 as shown in Figure 9.

Block B4--type 2 monolith

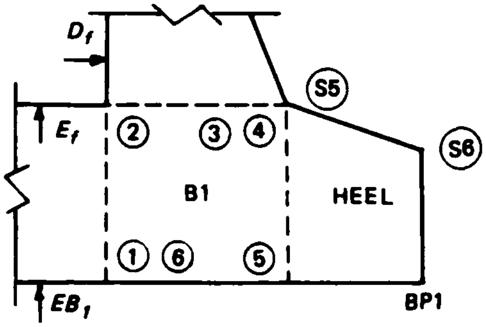
67. For a standard type 2 monolith, block B4 occupies the intersection of the culvert roof slab with the exterior culvert wall. The geometry of block B4 is shown in Figure 18.



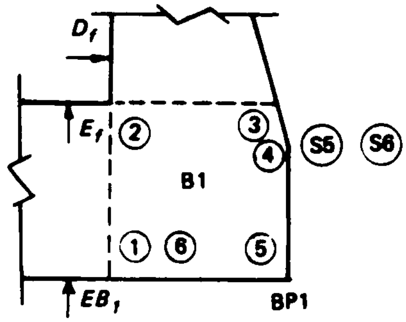
a. With heel



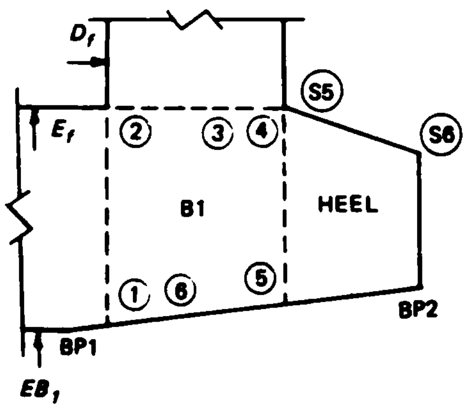
b. No heel



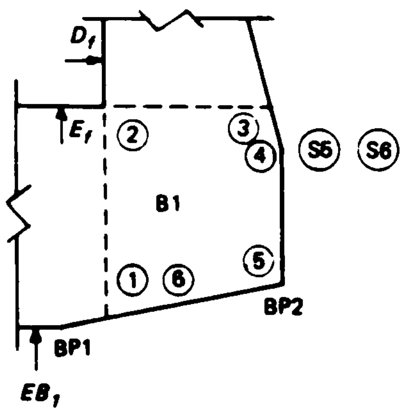
c. With heel



d. No heel



e. With heel



f. No heel

Figure 14. Example geometries of rigid block B1 for type 1 monoliths

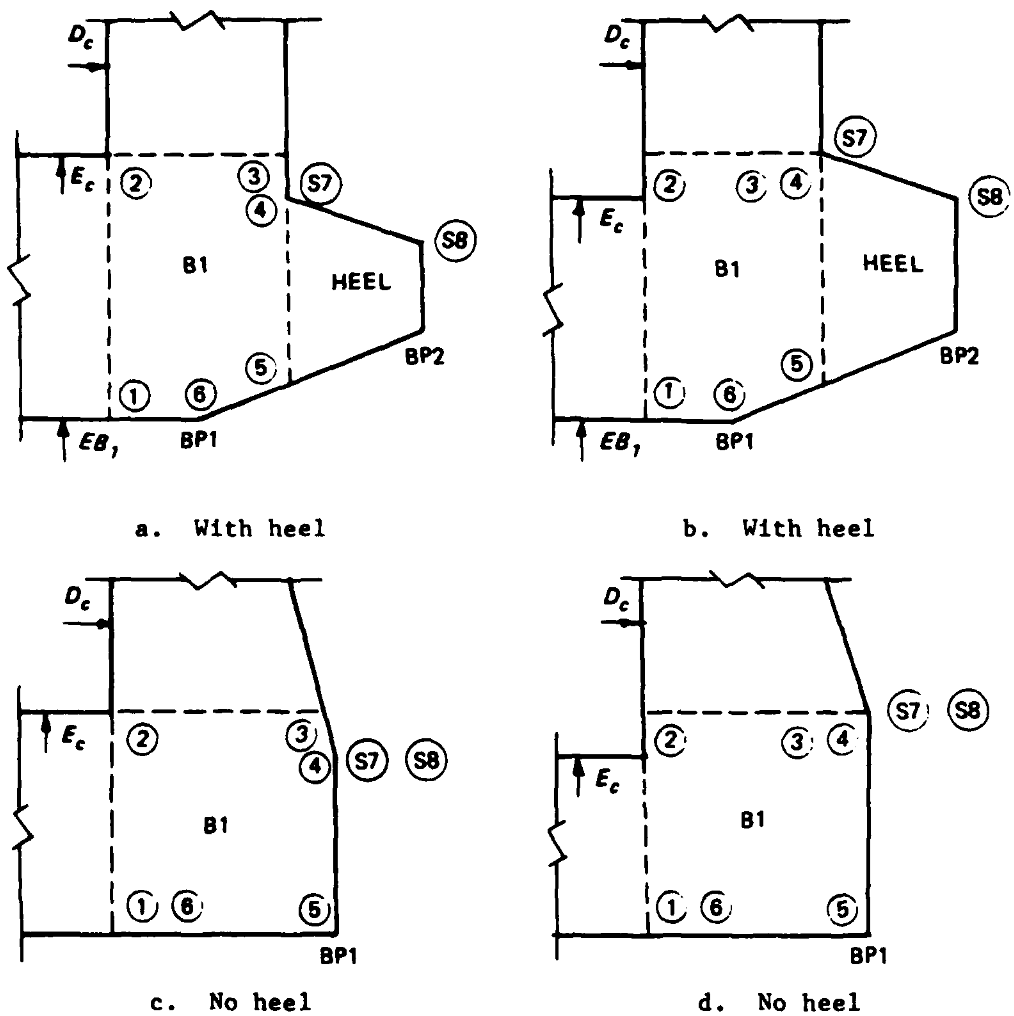
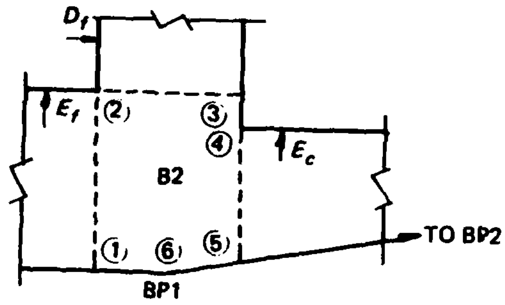
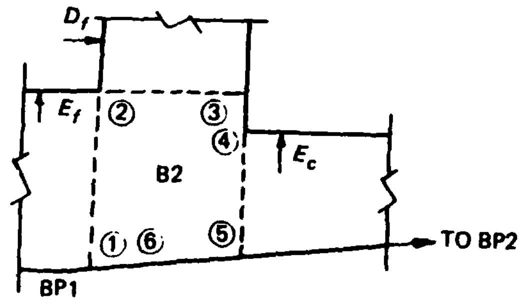


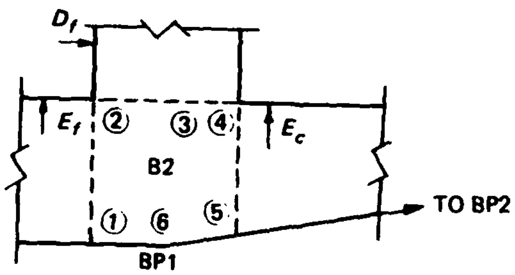
Figure 15. Example geometries for rigid blo-k B1 for type 2 (or 3) monoliths (for types 31 and 33 monoliths, replace S7, S8 by S6, S7; for types 32 and 34 monoliths, replace S7, S8 by S4, S5)



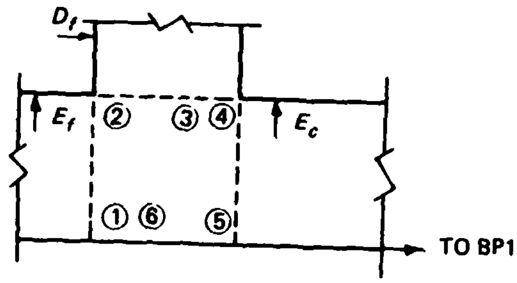
a. 2 base points



b. 2 base points



c. 2 base points



d. 1 or 2 base points

Figure 16. Example geometries of rigid block B2 for type 2 or 3 monoliths

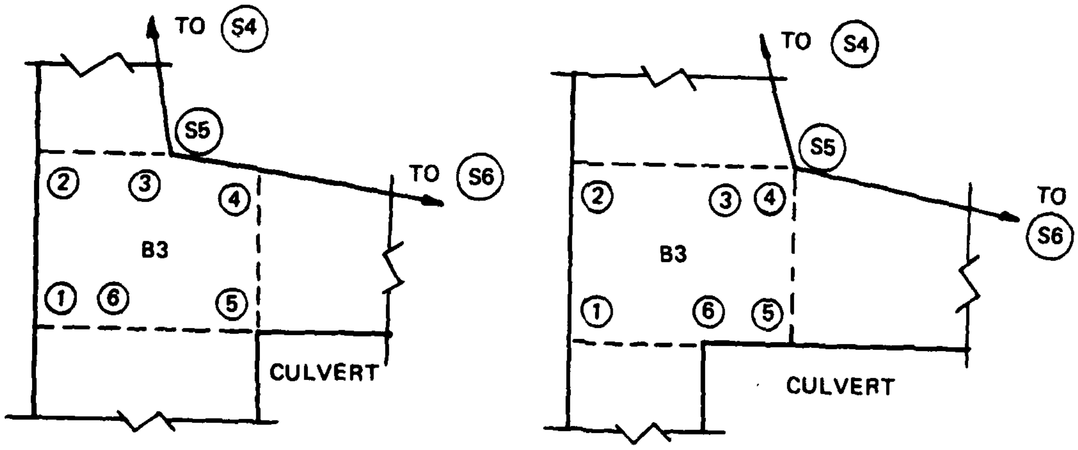


Figure 17. Example geometries for rigid block B3 for type 2 monoliths, standard case

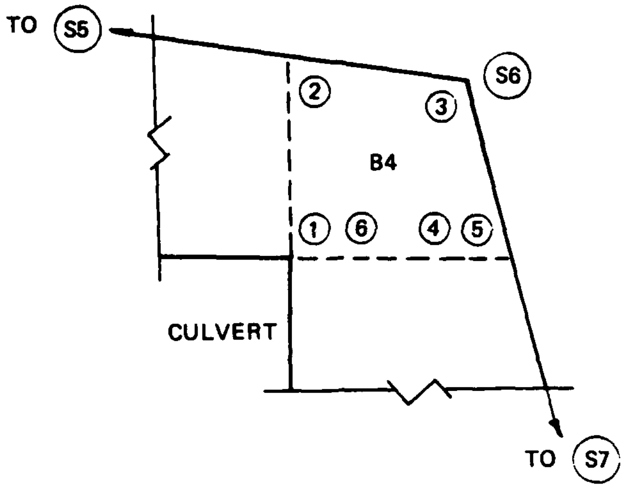


Figure 18. Rigid block B4 for type 2 monolith, standard case

Block B3--type 3 monolith

68. For types 31 and 33 monoliths, block B3 occupies the intersection of the interior culvert wall, the interior void wall, and the slab separating the culvert and void as illustrated in Figure 19a. Block B3 degenerates to a line for types 32 and 34 monoliths as shown in Figure 19b. For the latter case, all points on block B3 are at the same elevation.

Block B4--type 3 monolith

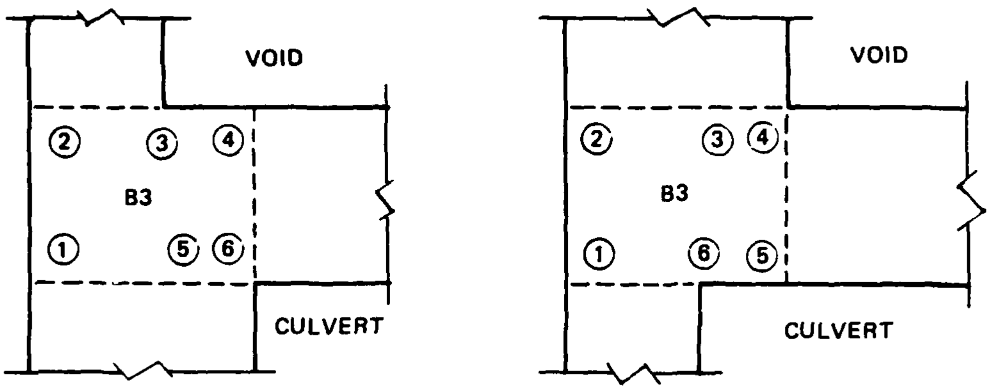
69. For types 31 and 33 monoliths, block B4 occupies the intersection of the exterior culvert wall, the exterior void wall, and the slab separating the culvert and void. Example geometries for these cases are shown in Figure 20a. For types 32 and 34 monoliths, block B4 degenerates to a line as illustrated in Figure 20b. In the latter case, all points are at the same elevation.

Block B5--type 3 monolith

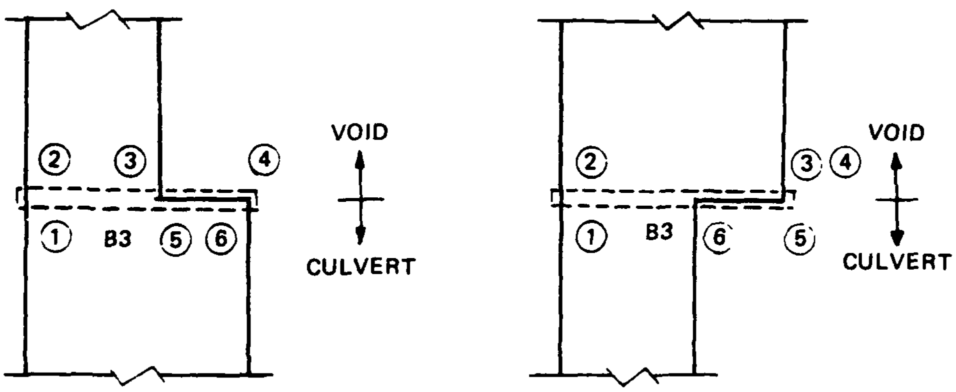
70. Block B5 occupies the rectangular area at the intersection of the interior void wall with the void roof slab for types 31 and 33 monoliths (see Figures 10 and 12). Block B5 may be interpreted to degenerate to a line at the top of the interior void wall for types 32 and 34 monoliths.

Block B6

71. Block B6 is assumed to be present in all monoliths, being the topmost part of the stem for types 1 and 2 and the intersection of the exterior void wall and void roof slab (if present) for type 3 monoliths. Example

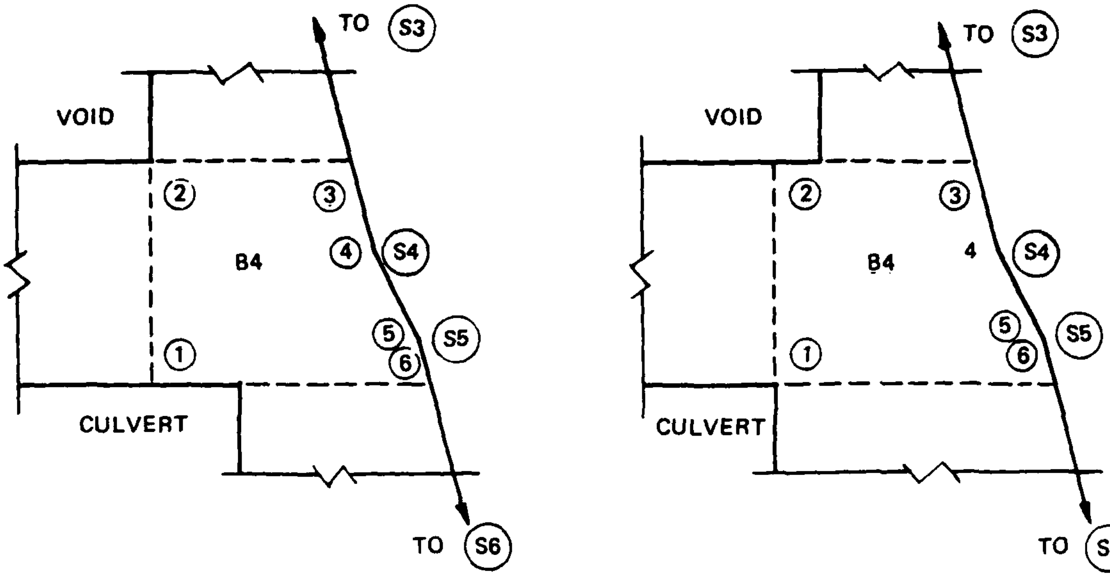


a. Type 31 or 33 monoliths

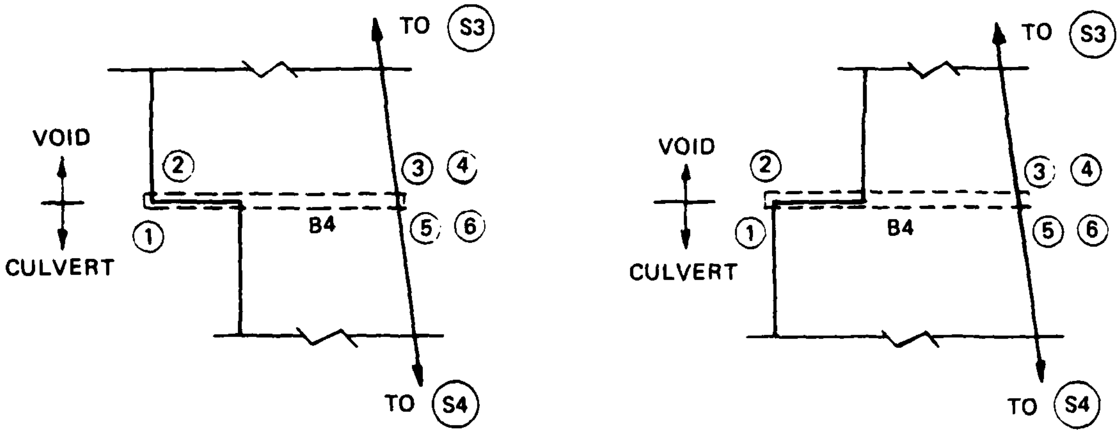


b. Type 32 or 34 monoliths

Figure 19. Example geometries for rigid block B3 for type 3 monoliths



a. Type 31 or 33 monoliths



b. Type 32 or 34 monoliths

Figure 20. Example geometries for rigid block B4 for type 3 monoliths

geometries are shown in Figures 21 and 22. (Note: By supplying three closely spaced stem points (S1, S2, S3) at the top of the stem, block B6 may be caused to degenerate into a line for types 1, 2, 32, and 34 monoliths without stem protrusions.)

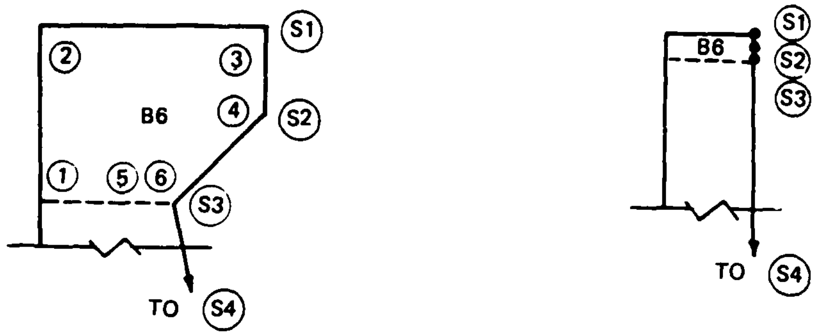
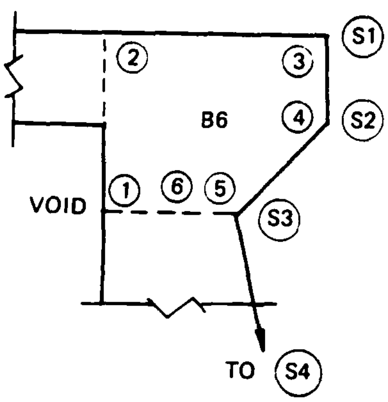
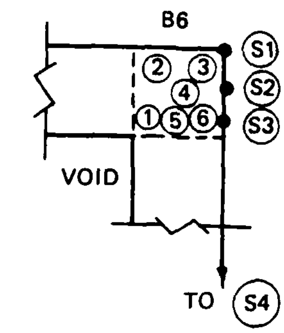


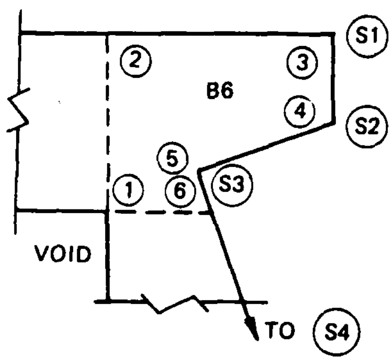
Figure 21. Example geometries for rigid block B6
for types 1 and 2 monoliths



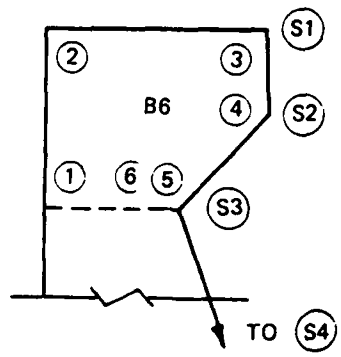
a. Type 31 or 32 monoliths



b. Type 31 or 32 monoliths



c. Type 31 or 32 monoliths



d. Type 33 or 34 monoliths

Figure 22. Example geometries for rigid block B6
for type 3 monoliths

Loads on Rigid Blocks

72. Any loads acting on the external surfaces of the rigid blocks, as well as the weight of the block, are converted into statically equivalent concentrated loads acting at the centroid of the rigid block.

Flexible Portions of Structure

73. The following portions of the structure are assumed to be capable of distortion under the influence of external loads:

a. The base slab from the chamber centerline to the interior boundary of block B1 for a type 1 monolith or block B2 for types 2 and 3 monoliths.

b. The base slab under the culvert between blocks B2 and B1 for types 2 and 3 monoliths.

c. If present, the heel beyond the exterior boundary of block B1 for all types.

d. The interior culvert wall between blocks B2 and B3 for types 2 and 3 monoliths.

e. The exterior culvert wall between blocks B1 and B4 (B3 for type 2, special case) for types 2 and 3 monoliths.

f. The culvert roof slab for type 2 standard monoliths and for types 31 and 33 monoliths.

g. The stem between blocks B1 and B6 for type 1 monoliths or between blocks B3 and B6 for type 2 monoliths.

h. The interior and exterior void walls in type 3 monoliths between blocks B3 and B5, and between blocks B4 and B6, respectively.

i. The void roof slab for types 31 and 32 monoliths.

Centerline of Flexible Portions

74. The boundaries of the rigid blocks in contact with the flexible portions of the structure are in all cases horizontal or vertical lines. Likewise, the vertical chamber centerline, the outside end of a heel (if present), a vertical line through an interior base point, and/or a horizontal line through an intermediate stem point (e.g., stem point S4 in a type 1 or 2 monolith) form additional horizontal and vertical boundaries at the ends of the flexible portions of the structures. The centerline of the flexible

portion is defined to be the straight line at middepth of each portion. This centerline is used to establish the locations of joints and to evaluate stiffness properties of the structural members in the model.

Joints in the Model

75. Joints in the frame model are established at the following locations in the structure:

- a. At middepth of the base slab at the chamber centerline.
- b. At points on the centerline of the flexible portions of the base slab (and heel) immediately above the intersection of a pile with the base (discussion of piles, paragraph 99).
- c. At an intermediate input base point if the point falls within the limits of a flexible portion.
- d. At middepth of the extreme heel end (if heel is present).
- e. At the centroid of each rigid block.
- f. At stem point S4 in types 1 and 2 monoliths.
- g. At the elevation of void ties in type 3 monoliths (discussion of void ties, paragraph 98).

Members in the Model

76. A structural member in the model is defined to be that portion of the structure which is between two joints.

Numbering of Joints and Members

77. Integer number identifiers are assigned to the joints and members as follows:

- a. Joints on the base are numbered beginning with (1) on the chamber centerline and proceeding sequentially outward to the extreme end of the base.
- b. Members in the base are numbered beginning with (1) for the member connected to the chamber centerline joint and proceeding sequentially outward.
- c. Joint numbers and member numbers assigned to the structural components above the base slab depend on the type of monolith.

78. Joint and member identifiers for several monoliths are illustrated in Figures 23, 24, and 25.

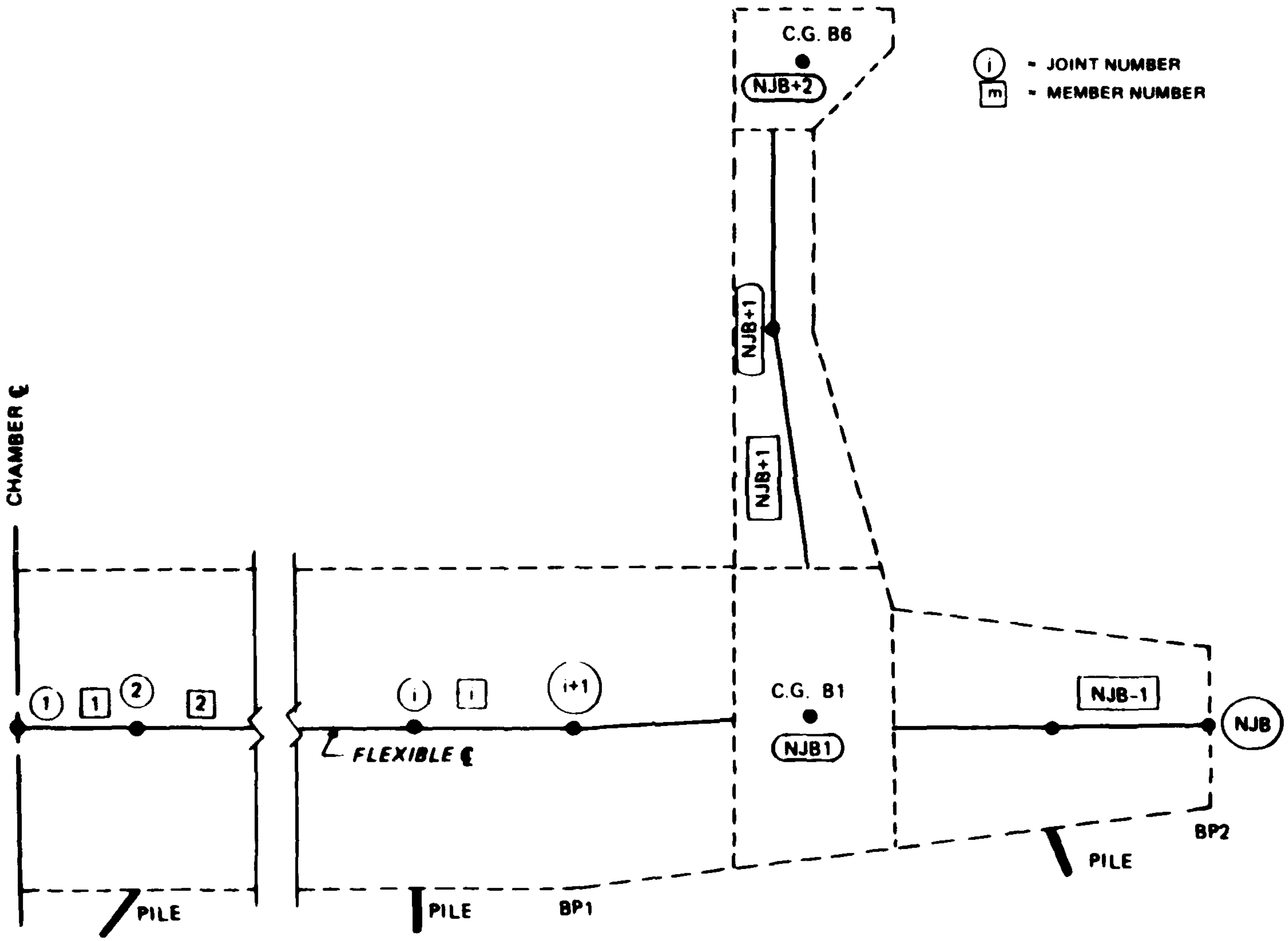


Figure 23. Joint and member numbers for type 1 monoliths

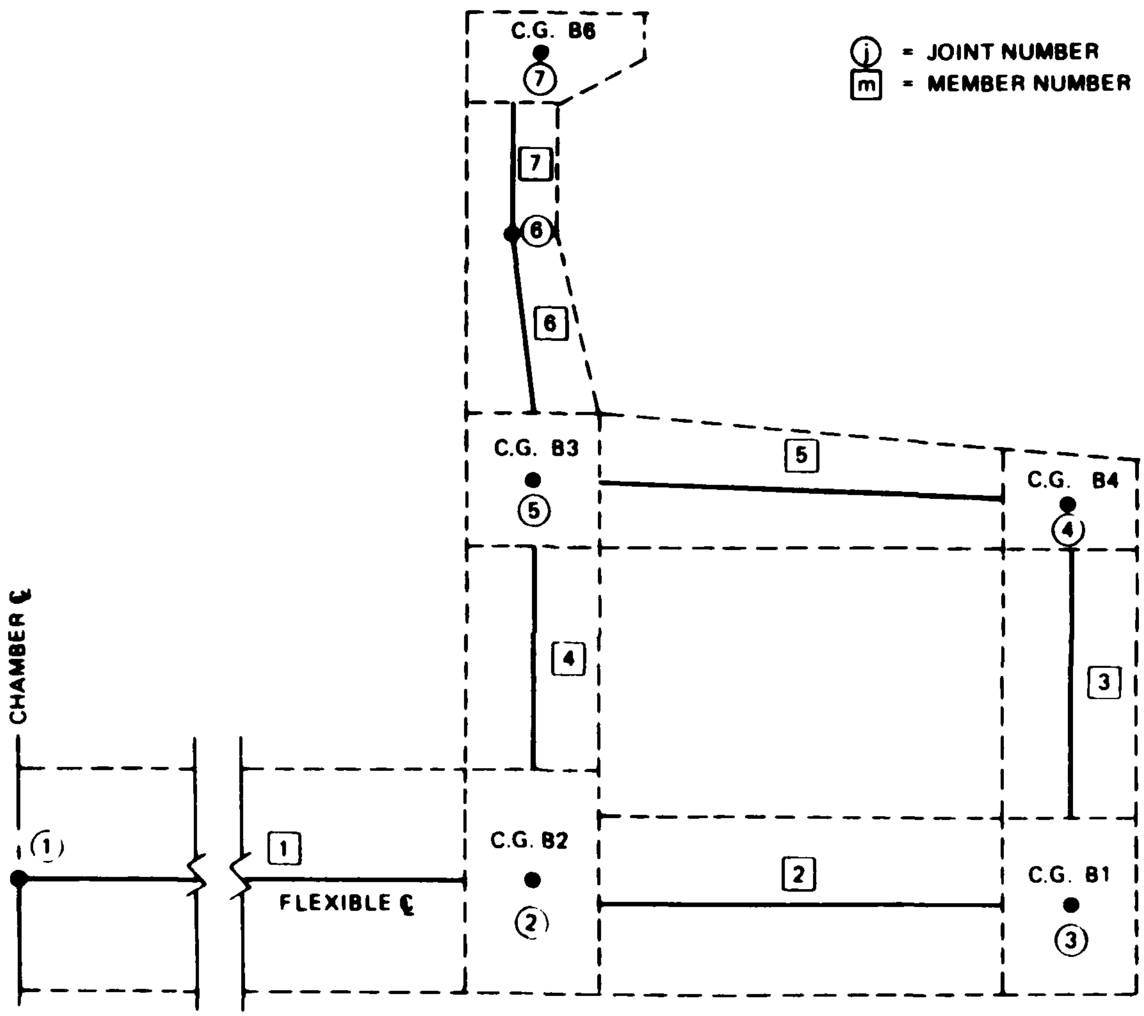


Figure 24. Example joint and member numbers for type 2 monoliths, standard case, with soil support

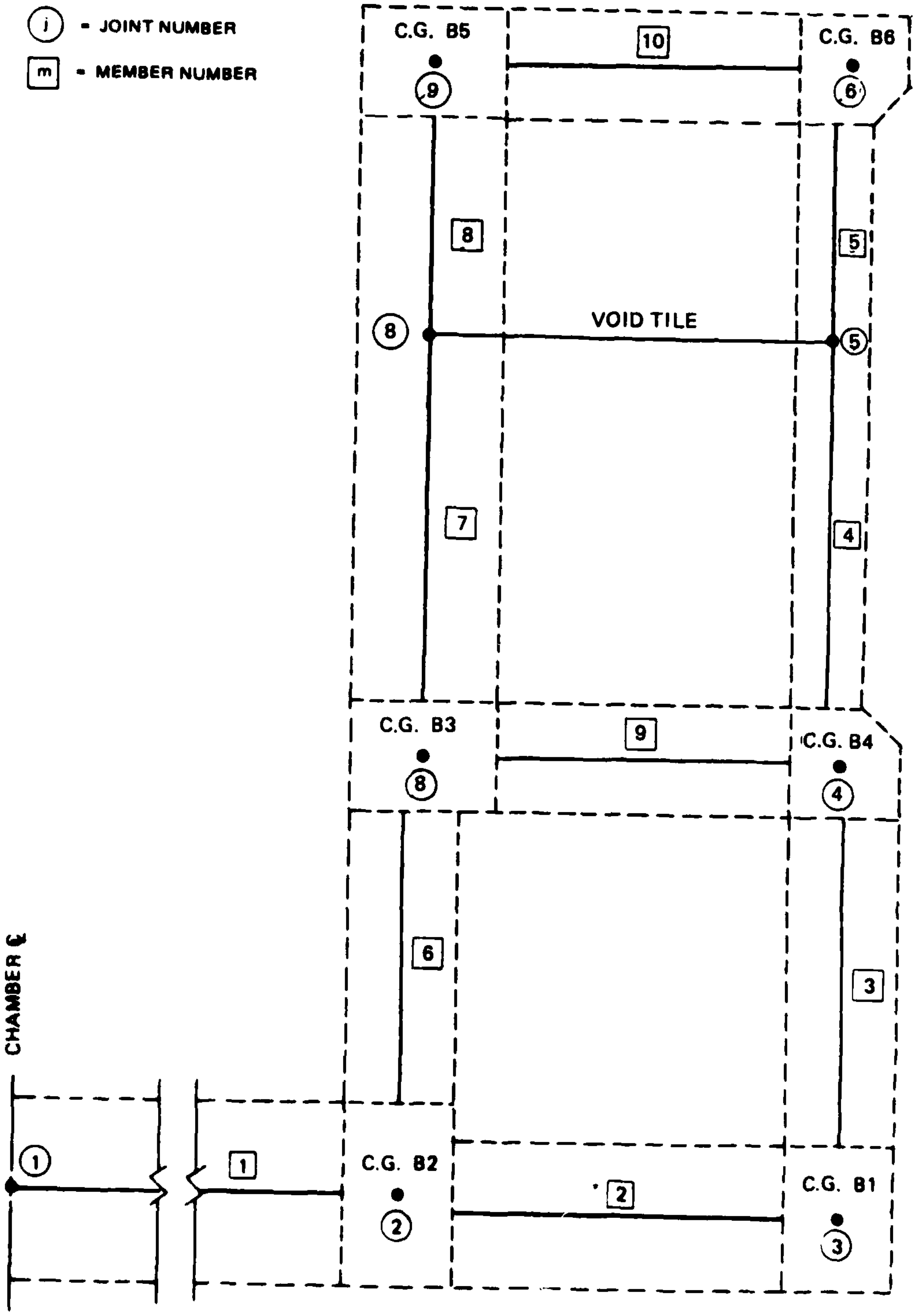


Figure 25. Example joint and member numbers for type 31 monoliths with soil support

Frame Member Dimensions

79. A member of the frame model may be connected to two intermediate joints (e.g., members 1 and 2 in Figure 23), to an intermediate joint at one end and to a rigid block at the other (e.g., members 6 and 7 in Figure 24), or may be connected to rigid blocks at each end (e.g., members 2 through 5 in Figure 24). In addition, the member cross section may be prismatic (e.g., member 1 in Figure 23) or may vary linearly (e.g., member 5 in Figure 24). In the following paragraphs, the evaluation of the member stiffness matrix and the assignment of various member characteristics are illustrated for a tapered member intersecting rigid blocks at each end.

80. A general tapered member is shown in Figure 26 (e.g., a base slab member under the culvert for a type 2 or 3 monolith). The connectivity of this member to the joints is expressed as "member m goes from joint i to joint j." The member flexible centerline intersects the vertical boundaries of the rigid blocks (at midheight) at points a' and b'. The cross-sectional dimensions are assessed from the vertical dimensions H_1 and H_2 at points a' and b' as illustrated. Hence the member cross section will be rectangular at each end with dimensions B wide (B = thickness of the 2-D slice) by H_1 deep at the left end and B by H_2 at the right end.

Member Flexible Length

81. A complex state of stress exists at the intersection of the member ends with the boundaries of the rigid blocks. Although the blocks have been described as rigid, there will be some deformation of the material at these interfaces. To account for this additional deformation, the flexible length of the member is extended into the blocks at each end to points a and b. The location of points a and b is established as follows. The horizontal distance from the rigid block centerline to the vertical interface is reduced by a user supplied factor S $(0 \le S \le 1)$. $S = 0$ extends point a or b to a vertical line through the block centroid; $S = 1$ places point a or b on the vertical interface (i.e., a, a' and b, b' coincide). The effect of the factor $\underline{S}$ is to shrink the size of the rigid blocks for flexibility assessment only; for other purposes (i.e., surface load transfer or piles intersecting the surface of a rigid block), the dimensions of the rigid blocks are unaffected.

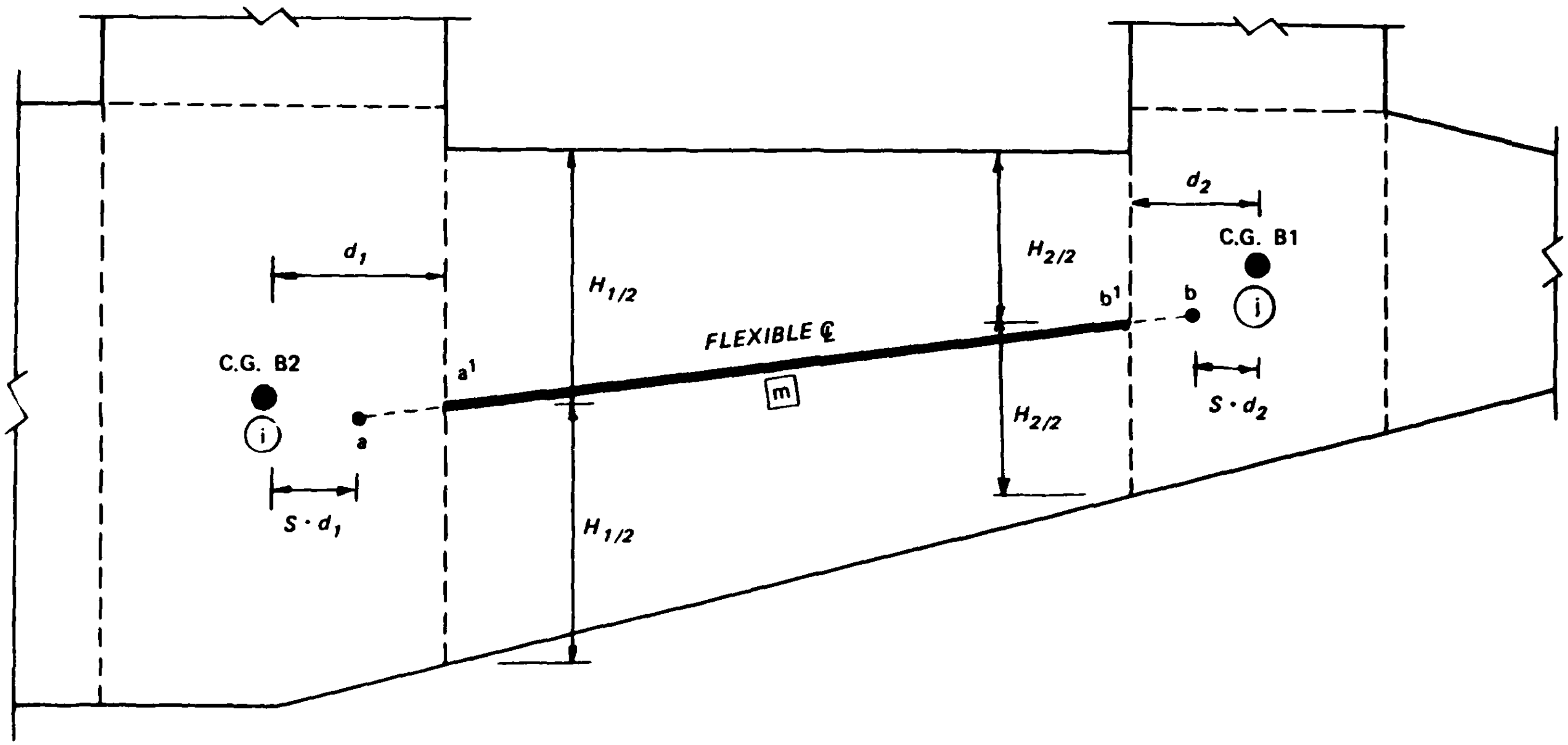


Figure 26. Member dimensions

82. For evaluation of the member stiffness matrix and fixed end forces, the member is treated as a flexible section between points a and b (with cross sections at a and b as described in paragraph 80). The ends of the flexible length (a and b) are connected to the end joints i and j (i.e., centroids of blocks) by rigid links as shown in Figure 27. This approximation, in effect, distorts the actual member shape. The effect of this distortion is felt not to introduce significant errors for lightly tapered members or where the factor S is approximately equal to 1 .

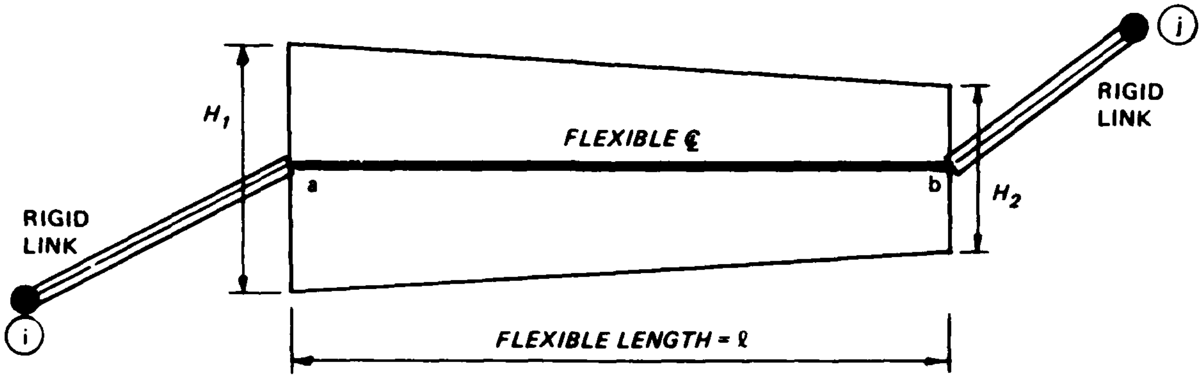


Figure 27. Equivalent frame member

Member Stiffness Matrix

83. The member stiffness matrix for the member which is connected to joints i and j relates forces at joints i and j to displacements at joints i and j and accounts for the effects of the flexible length of the member and the effects of the rigid links at each end. This force-displacement relationship is initially established for a local righthand Cartesian coordinate system (x , y , z with the origin at a , the x-axis along the member flexible centerline positive toward b, and the z-axis positive outward from the plane of the figure). Forces on the ends of the flexible length related to the local coordinate system are shown in Figure 28.

84. At any point on the member ($\varepsilon = x/\ell$), the internal stress resultants are related to the member end forces at a by

$$P_{\xi} = -f_{xa}$$

$$V_{\xi} = f_{ya}$$

$$M_{\xi} = f_{ya}\ell\xi - m_a$$

where

P_{ξ} = axial stress resultant at ξ

V_{ξ} = shear force at ξ

M_{ξ} = bending moment at ξ

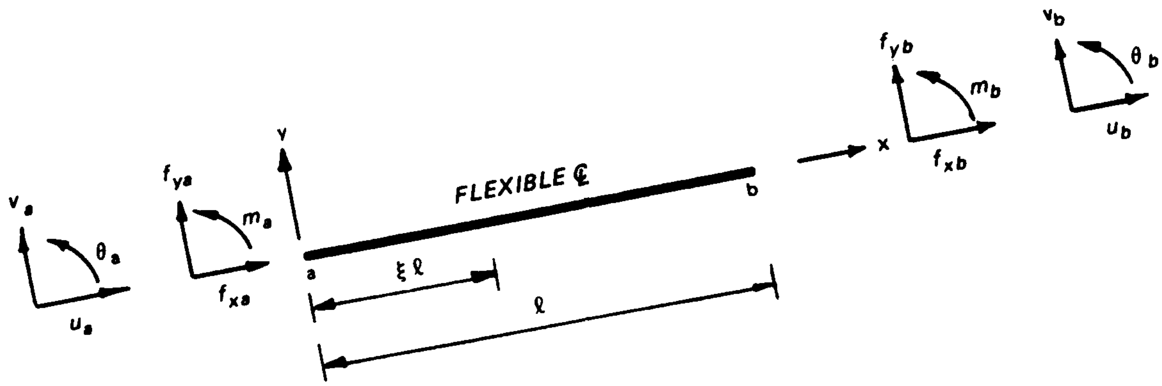


Figure 28. Member end forces and displacements in member coordinate system

85. Employing classical structural mechanics, the relationships between the forces and displacements at end a are expressed by

$$u_a = \frac{f_{xa}\ell}{E}\int_{\xi=0}^{\xi=1}\frac{d\xi}{A_{\xi}}$$

$$v_a = \frac{f_{ya}\ell^3}{E}\left(\int_{\xi=0}^{\xi=1}\frac{\xi^2 d\xi}{I_{\xi}} + \frac{E}{G\ell^2}\int_{\xi=0}^{\xi=1}\frac{d\xi}{A_{v\xi}}\right) - \frac{m_a\ell^2}{E}\int_{\xi=0}^{\xi=1}\frac{\xi d\xi}{I_{\xi}}$$

$$\theta_a = -\frac{f_{ya}\ell^2}{E}\int_{\xi=0}^{\xi=1}\frac{\xi d\xi}{I_{\xi}} + \frac{m_a\ell}{E}\int_{\xi=0}^{\xi=1}\frac{d\xi}{I_{\xi}}$$

where

A_ξ = cross-sectional area at ξ

$$= B[H_1(1 - \xi) + H_2(\xi)] = BH_1\left(1 + \frac{H_2 - H_1}{H_1}\,\xi\right)$$

$$= A_o(1 + c\xi)$$

I_ξ = cross-sectional moment of inertia at ξ

$$= \frac{BH_1^3}{12}(1 + c\xi)^3 = I_o(1 + c\xi)^3$$

$A_{v\xi}$ = shear area at ξ

$$= \frac{A_o}{1.2}(1 + c\xi)$$

E = modulus of elasticity

G = shear modulus = $E/[2(1 + \nu)]$

ν = Poisson's ratio

86. Evaluation of the integrals above yields:

$$u_a = \frac{f_{xa}\ell}{EA_o}\,\frac{Ln(1 + c)}{c}$$

(Ln = Naperian logarithm)

$$v_a = \frac{f_{ya}\ell^3}{EI_o}\left\{\frac{1}{c^3}\left[Ln\ (1 + c) - \frac{c(2 + 3c)}{2(1 + c)^2}\right] + \phi\,\frac{Ln\ (1 + c)}{c}\right\} - \frac{M_a\ell^2}{EI_o}\left[\frac{1}{2(1 + c)^2}\right]$$

$$\phi = \frac{1.2EI_o}{GA_o\ell^2}$$

$$\theta_a = -\frac{f_{ya}\ell^2}{EI_o}\left[\frac{1}{2(1 + c)^2}\right] + \frac{M_a\ell}{EI_o}\left[\frac{2 + c}{2(1 + c)^2}\right]$$

87. Inversion of the equations of paragraph 86 gives the following relationship between forces and displacements at a.

$$\begin{Bmatrix} f_{xa} \\ f_{ya} \\ M_a \end{Bmatrix} = \begin{bmatrix} k_{11} & 0 & 0 \\ 0 & k_{22} & k_{23} \\ 0 & k_{32} & k_{33} \end{bmatrix} \begin{Bmatrix} U_a \\ V_a \\ \theta_a \end{Bmatrix}$$

(Note $k_{32} = k_{23}$)

88. Finally, the entire member force-displacement relationship is expressed as

$$\begin{Bmatrix} f_{xa} \\ f_{ya} \\ M_a \\ f_{xb} \\ f_{yb} \\ M_b \end{Bmatrix} = \begin{bmatrix} k_{11} & 0 & & -k_{11} & 0 & 0 \\ & k_{22} & k_{23} & 0 & -k_{22} & (k_{22}\ell - k_{23}) \\ & & k_{33} & 0 & -k_{23} & (k_{23}\ell - k_{33}) \\ & & & k_{11} & 0 & 0 \\ & \text{SYM} & & & k_{22} & (k_{23} - k_{22}\ell) \\ & & & & & (k_{22}\ell^2 - 2k_{23} + k_{33}) \end{bmatrix} \begin{Bmatrix} U_a \\ V_a \\ \theta_a \\ U_b \\ V_b \\ \theta_b \end{Bmatrix}$$

or $\underset{\sim}{f} = \underset{\sim}{k}'\underset{\sim}{u}$

89. For a prismatic member, $c = 0$, the stiffness coefficients become:

$$k_{11} = \frac{EA}{\ell}$$

$$k_{22} = \frac{12EI}{\ell^3(1 + 12\phi)}$$

$$k_{23} = \frac{6EI}{\ell^2(1 + 12\phi)}$$

$$k_{33} = \frac{4EI}{\ell}\frac{(1 + 3\phi)}{(1 + 12\phi)}$$

Transformation to Global Coordinates

90. Prior to imposing the effects of the rigid links, the member force-displacement relationship is transformed to relate force components at ends $\underline{a}$ and $\underline{b}$ to displacement components in the global coordinate system. (The global coordinate system has x horizontal and y vertical; the global z axis is coincident with the local z axis.) This transformation results in:

$$\tilde{F}_{ab} = \tilde{R}^T \tilde{k}' \tilde{R} \tilde{U}_{ab}$$

or

$$\tilde{F}_{ab} = \tilde{k} \tilde{U}_{ab}$$

where

$\tilde{F}_{ab}$ = 6x1 vector of global force components at $\underline{a}$ and $\underline{b}$

$\tilde{R}$ = transformation matrix

$$= \begin{bmatrix} c_x & c_y & 0 & 0 & 0 & 0 \\ -c_y & c_x & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & c_x & c_y & 0 \\ 0 & 0 & 0 & -c_y & c_x & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

c_x = cosine of the angle between local x and global x

c_y = cosine of the angle between local x and global y

$\tilde{R}^T$ = transpose of $\tilde{R}$

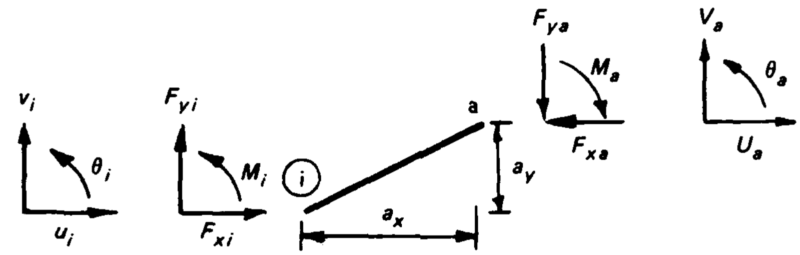
$\tilde{U}_{ab}$ = 6x1 vector of global displacement components at $\underline{a}$ and $\underline{b}$

$\tilde{k}'$ = local stiffness matrix

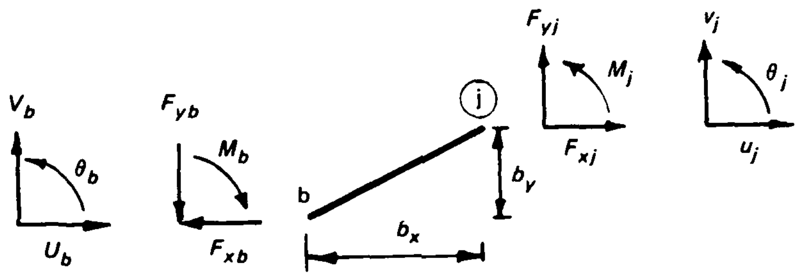
$\tilde{k}$ = global stiffness matrix

Effect of Rigid Links

91. Free body diagrams of the rigid links at the ends of the member are shown in Figure 29. All force and displacement components as well as the



a. End a



b. End b

Figure 29. Free body diagrams of rigid links

dimensions of the rigid links are parallel to the global coordinates. Equilibrium and kinematic analysis of the rigid links provides:

$$\begin{Bmatrix} U_a \\ V_a \\ \theta_a \\ U_j \\ V_j \\ \theta_j \end{Bmatrix} = \begin{bmatrix} 1 & 0 & -a_y & 0 & 0 & 0 \\ 0 & 1 & a_x & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & b_y \\ 0 & 0 & 0 & 0 & 1 & -b_x \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{Bmatrix} U_i \\ V_i \\ \theta_i \\ U_j \\ V_j \\ \theta_j \end{Bmatrix}$$

or

$$\underset{\sim}{U}_{ab} = \underset{\sim}{D}\underset{\sim}{U}_{ij}$$

and

$$\begin{Bmatrix} F_{xi} \\ F_{yi} \\ M_i \\ F_{xj} \\ F_{yj} \\ M_j \end{Bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ -a_y & a_x & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & b_y & -b_x & 1 \end{bmatrix} \begin{Bmatrix} F_{xa} \\ F_{ya} \\ M_a \\ F_{xb} \\ F_{yb} \\ M_b \end{Bmatrix}$$

or

$$\underset{\sim}{F}_{ij} = \underset{\sim}{D}^T \underset{\sim}{F}_{ab}$$

92. Combination of the relationship of paragraphs 90 and 91 results in

$$\underset{\sim}{F}_{ij} = \underset{\sim}{D}^T \underset{\sim}{R}^T \underset{\sim}{k}' \underset{\sim}{R}\underset{\sim}{D}\underset{\sim}{U}_{ij} = \underset{\sim}{K}_{ij}\underset{\sim}{U}_{ij}$$

where $\underset{\sim}{K}_{ij}$ is the global stiffness matrix of the member connected to joints i and j , including the effect of rigid links.

Member Fixed End Forces

93. Due to the surrounding soil and water, the external surfaces of a member are subjected to distributed normal and tangential forces and possibly concentrated forces. Only those forces which act on the member between the vertical boundaries of the rigid blocks (between points a' and b' , Figure 26) are treated as member loads. A priori all surface loads are resolved into components parallel and perpendicular to the member flexible centerline. The contributions of member loads to member fixed end forces are approximated as follows.

94. A member and surface loads are illustrated in Figure 30 for an essentially horizontal member. (For an essentially vertical member, interchange

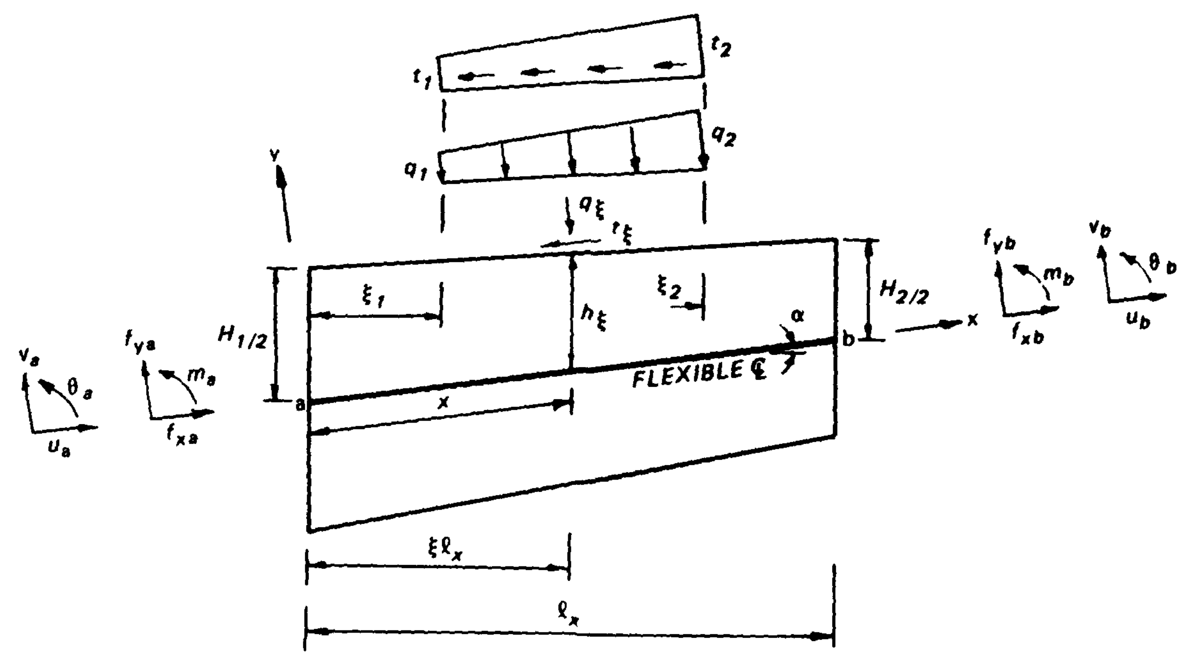


Figure 30. Member surface loads

the descriptions horizontal and vertical in the following discussion.) The member is bounded by vertical lines through the ends of the flexible length (through a and b). Surface loads perpendicular (q) and parallel (t) to the member flexible centerline are shown on the top surface. These surface loads vary linearly from q_1, t_1, to q_2, t_2 between the limits of $\xi = \xi_1$ to $\xi = \xi_2$ where ξ is a dimensionless coordinate defined by $\xi = x/\ell$, where x is the local coordinate of generic point (p) and ℓ is the flexible length of the member. The magnitude of the distributed loads at a generic point p' on the surface immediately above (vertical) (p) are given by

$$q_\xi = q_1(1 - \xi) + q_2\xi$$

and

$$t_\xi = t_1(1 - \xi) + t_2\xi$$

and the vertical distance from p to p' is given by

$$h_\xi = \frac{H_1(1 - \xi) + H_2\xi}{2}$$

If the displacements of point p are u , v , and θ (components parallel to the local coordinate system), the displacements of the surface point p' may be expressed as (ignoring the small deformations of the cross section)

$$u_s = u - \sigma h_\xi \cdot C_\alpha \theta$$

$$v_s = v + \sigma h_\xi \cdot S_\alpha \theta$$

where

σ = +1 for loads on top surface, = 0 for self weight of member,
= -1 for loads on bottom surface

C_α = cosine of α

S_α = sine of α

The displacements of the generic point p may in turn be expressed in terms of the end displacements at a and b as

$$u = \psi_1(\xi)u_a + \psi_4(\xi)u_b$$

$$v = \psi_2(\xi)v_a + \psi_3(\xi)\theta_a + \psi_5(\xi)v_b + \psi_6(\xi)\theta_b$$

$$\theta = \frac{dv}{dx}$$

where $\psi_n(\xi)$ is an interpolation function of ξ to be discussed later. By the process of virtual work, the fixed end forces at a and b are evaluated for unit values of the end displacements as

$$f_{xa} = \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (u_a = 1 \text{ , others } 0)$$

$$f_{ya} = \ell_s \int_{\xi_1}^{\xi_2} q_\xi v_s d\xi + \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (v_a = 1 \text{ , others } 0)$$

$$M_a = \ell_s \int_{\xi_1}^{\xi_2} q_\xi v_s d\xi + \ell_s \int_{\xi_1}^{\xi_2} t_\xi u_s d\xi \qquad (\theta_a = 1 \text{ , others } 0)$$

f_{xb} , f_{yb} , and M_b are obtained from the above expressions for $u_b = 1$, $v_b = 1$, and $\theta_b = 1$ with other displacements zero, respectively.

95. The interpolation functions $\psi_n(\xi)$ of paragraph 94 relate displacements at a generic point on the member centerline of an unloaded member to displacements at the ends of the member. Such functions are available onlv for a prismatic member in which shear distortions are negligible or where the distributed loads are uniformly distributed. A variety of structures have been analyzed to investigate the degree of approximation introduced bv using prismatic member interpolation functions for tapered members. It is felt that no appreciably significant errors are produced for the ordinary geometries usually encountered in U-frame structures. However, no information is available related to the magnitude of errors in severely tapered members or for cases where loadings are significantly nonuniform. The interpolation functions used in the current analysis are

$$\psi_1 = 1 - \xi$$

$$\psi_2 = 2\xi^3 - 3\xi^2 + 1$$

$$\psi_3 = (\xi^3 - 2\xi^2 + \xi)\ell$$

$$\psi_4 = \xi$$

$$\psi_5 = -2\xi^3 + 3\xi^2$$

$$\psi_6 = (\xi^3 - \xi^2)\ell$$

96. The fixed end forces at the ends of the flexible length are transformed to global coordinate components and thence through the rigid links at the member ends to yield

$$\underset{\sim}{F}_{eij} = \underset{\sim}{D}^T \underset{\sim}{R}^T \underset{\sim}{F}_{eab}$$

where

$\underset{\sim}{F}_{eij}$ = 6x1 vector of fixed end forces at joints i and j in global coordinate directions

$\underset{\sim}{R}$ = 6x6 coordinate transformation matrix from paragraph 90

$\underset{\sim}{D}$ = 6x6 rigid link transformation matrix from paragraph 91

$\underset{\sim}{F}_{eab}$ = 6x1 vector of fixed end forces at the ends of the flexible length in local coordinate directions

97. The final relationship between member end forces, member end displacements, and member loads in the global coordinate system is

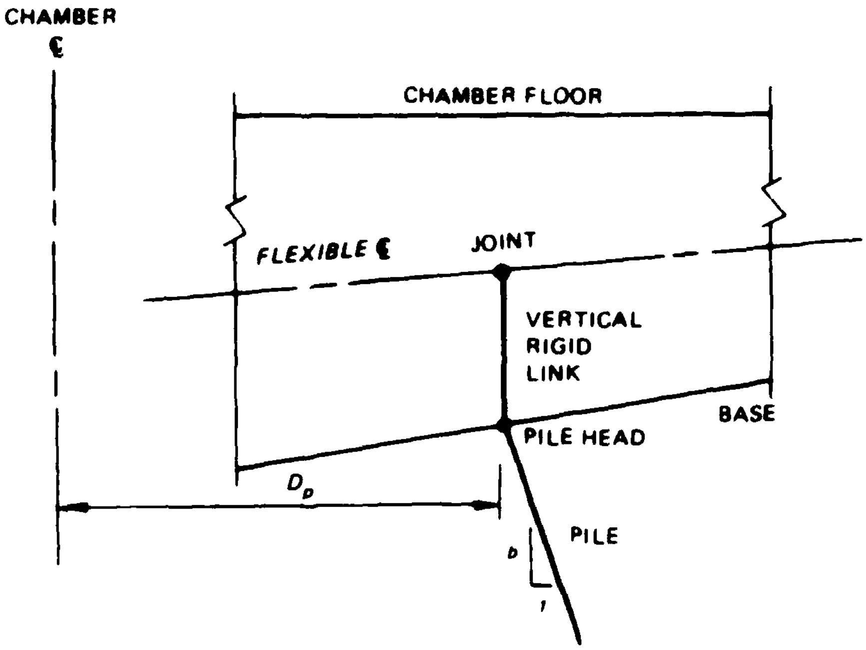
$$\underset{\sim}{F}_{ij} = \underset{\sim}{K}\underset{\sim}{U}_{ij} + \underset{\sim}{F}_{eij}$$

Void Tie Members

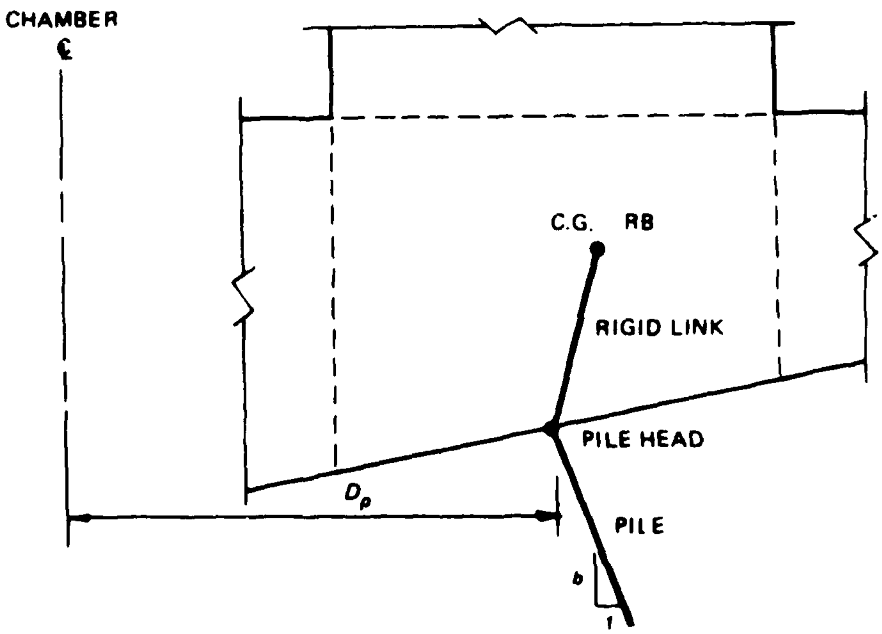
98. A facility for enforcing interaction between the vertical walls of the void openings is provided for type 3 monoliths. Fictitious horizontal structural members may be described as connecting the void walls at one or more elevations. These ties are assumed to behave as truss members (i.e., only possessing axial stiffness). No guidance for the application of this facility is provided herein.

Pile Foundation

99. Piles attached to the base of the structure are treated as elastic elements which develop resistance proportional to the displacements at the pile head/structure base point of connection. The locations of pile head/structure base attachment points are provided by pile layout data which give the distance from the chamber centerline to the pile head. The piles may be battered or vertical. A typical pile situation is shown in Figure 31.



a. Pile head intersects flexible region



b. Pile head intersects rigid block

Figure 31. Pile-structure connections

100. The distance, D_p, from the chamber centerline to the pile head provided by pile layout data with base point distances and elevations determine the point at which the pile head is attached to the structure base. If the pile intersects a flexible portion of the structure base, a joint in the frame model is defined on the flexible centerline at a point immediately above the pile head. In this case, the pile head is assumed to be attached to the frame joint as illustrated in Figure 31a. If the pile intersects the base anywhere on the periphery of a rigid block, the pile head is connected to the joint at the rigid block centroid by a rigid link as shown in Figure 31b. (Note: When the pile head intersects the flexible portion of the base in the immediate vicinity of a rigid block, the flexible length of the base member between the "pile joint" and the rigid block may be extremely short and can lead to severe roundoff errors in the analysis. This condition should be avoided if at all possible.)

Pile Head Force-Displacement Relationships

101. Forces and displacements for a pile and the attendant rigid link are shown in Figure 32. The relationship between pile head forces and displacements with components parallel and perpendicular to the axis of the pile is

$$\begin{Bmatrix} f_{xp} \\ f_{yp} \\ M_p \end{Bmatrix} = \begin{bmatrix} B_{11} & 0 & B_{13} \\ & B_{22} & 0 \\ \text{SYM} & & B_{33} \end{bmatrix} \begin{Bmatrix} u_p \\ v_p \\ \theta_p \end{Bmatrix}$$

or

$$\underset{\sim}{f}_p = \underset{\sim}{k}'_p \underset{\sim}{U}_p$$

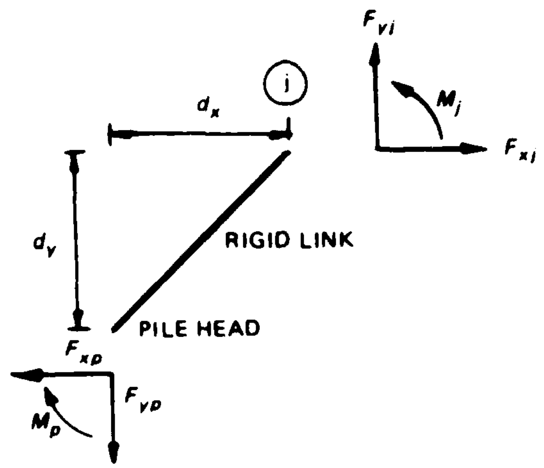
where

f_{xp} = pile head shear force
f_{yp} = pile head axial force
M_p = pile head moment

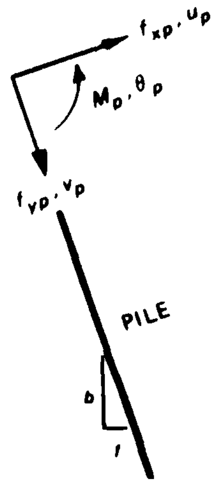
B_{11}, B_{22}, B_{33}, B_{13} = pile head stiffness coefficients which may be supplied directly by the user or calculated internally by the program as discussed below

u_p, v_p = translation components of displacement perpendicular and parallel to the pile axis, respectively

θ_p = pile head rotation



a. Free body diagram of pile rigid link



b. Pile head forces and displacements

Figure 32. Pile forces and displacements

102. The above relationship is transformed to global coordinates for a battered pile by

$$\underset{\sim}{F}_p = \underset{\sim}{R}_p^T \underset{\sim}{k}'_p \underset{\sim}{R}_p \underset{\sim}{U}_p$$

where

$\underset{\sim}{F}_p$ = 3x1 vector of pile head forces parallel to global coordinates (horizontal and vertical)

$\underset{\sim}{R}_p$ = 3x3 transformation matrix

$$= \begin{bmatrix} C_1 & C_2 & 0 \\ -C_2 & C_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad C_1 = \frac{|b|}{\sqrt{1 + b^2}} \qquad C_2 = \frac{|b|}{b} C_1$$

b = pile batter

$\underset{\sim}{U}_p$ = 3x1 vector of pile head displacements in global coordinate directions

103. Finally, the pile head force-displacement relationship is transformed through the rigid link to yield

$$\underset{\sim}{F}_{pj} = \underset{\sim}{D}_p^T \underset{\sim}{R}_p^T \underset{\sim}{k}'_p \underset{\sim}{R}_p \underset{\sim}{D}_p \underset{\sim}{U}_j$$

where

$\underset{\sim}{F}_{pj}$ = 3x1 vector of pile forces acting on joint j

$$\underset{\sim}{D}_p = \begin{bmatrix} 1 & 0 & dx \\ 0 & 1 & -dy \\ 0 & 0 & 1 \end{bmatrix}$$

dx, dy = horizontal and vertical projections of pile rigid link

$\underset{\sim}{U}_j$ = 3x1 vector of joint j displacements

Pile Head Stiffness Matrix

104. As stated above, the pile head stiffness coefficients B_{11}, B_{22}, B_{33}, and B_{13} may be supplied as input. However, provision is made for evaluating these coefficients from pile/soils data. When the pile head

stiffness matrix is calculated by the program, the following parameters are required as input data:

- E = modulus of elasticity of pile material
- A = pile cross-sectional area
- I = pile cross-sectional moment of inertia
- L = pile length
- D_f = pile head fixity coefficient
- k_A = axial stiffness coefficient
- S_1, S_2 = soil stiffness coefficients for lateral resistance which varies linearly from S_1 at the pile head to $S_y = S_1 + S_2 y$ at any distance below the pile head

Axial Stiffness

105. The axial stiffness coefficient is evaluated as

$$B_{22} = k_A \frac{EA}{L}$$

Lateral Stiffness Coefficients for Fixed Head Pile (D_f = 1)

106. The lateral stiffness coefficients are determined from numerical solutions of the general differential equation

$$EI \frac{d^4 u}{dy^4} + (S_1 + S_2 y)u = 0$$

where E, I, S_1, and S_2 are defined above; u is the lateral pile displacement; and y is the distance along the pile axis. By definition, for a fixed head pile (see Figure 31 for notation)

B_{11} = force f_{xp} due to $u_p = 1$, $\theta_p = 0$

B_{13} = moment M_p due to $u_p = 1$, $\theta_p = 0$

B_{33} = moment M_p due to $u_p = 0$, $\theta_p = 1$

Lateral Stiffness Coefficients for Pinned Head Pile ($D_f = 0$)

107. For a pinned head pile, M_p (and hence B_{13}, B_{33}) are identically zero. B_{11} is obtained by solution of the above differential equation for the case

$$u_p = 1 , \quad M_p = 0$$

Lateral Stiffness Coefficients for Partially Fixed Head Pile ($0 \le D_f \le 1$)

108. Effects of partial head fixity on the lateral stiffness coefficients are evaluated as:

a. The rotation $\theta_p = \theta_{po}$ for pinned head pile with $u_p = 1$, $M_p = 0$ is determined.

b. Coefficients B_{11} and B_{13} are obtained from the head forces due to $u_p = 1$, $\theta_p = (1 - D_f)\theta_{po}$.

c. Coefficient B_{33} is obtained from the head forces due to $u_p = 0$, $\theta_p = D_f \cdot \theta_{po}$.

Vertical Piles on Chamber Centerline

109. When the pile system is symmetric about the chamber centerline, only the data describing the piles on the rightside of the structure are required as input and the computer program automatically generates a mirror image description for the piles on the leftside. An ambiguity arises in a symmetric system when a vertical pile is attached at the centerline of the structure where a strict mirror image would result in doubling the effects of vertical centerline piles. In the computer program, the stiffness effects of vertical centerline piles in symmetric systems are evaluated for only a single pile and one half of the pile stiffness matrix is assigned to each side of the structure.

Method of Solution

110. The force-displacement relationships for the frame members and piles (if present) are assembled into a force-displacement relationship of the form

$$\underset{\sim}{F} = \underset{\sim}{k}\underset{\sim}{U} + \underset{\sim}{F}_e$$

where, for a system with n joints,

- $\underset{\sim}{F}$ = 3nx1 vector of loads applied directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressures
- $\underset{\sim}{k}$ = 3nx3n structure stiffness matrix composed of structure member stiffness matrices, pile head stiffness matrices, and void tie stiffnesses
- $\underset{\sim}{U}$ = 3nx1 vector of joint displacements
- $\underset{\sim}{F}_e$ = 3nx1 vector of member fixed end forces

The 3n simultaneous equations are solved by Gauss elimination, for the joint displacements. Known displacements are substituted into the various member end force-displacement relations and pile head force-displacement relations to obtain member end forces and pile head forces.

Restraint of Rigid Body Motions

111. In a pile-supported system, the piles act as linearly elastic supports which inhibit rigid body motions of the system and no additional support specifications are necessary. However, in a soil-supported system, once equilibrium of all forces has been established, there are no supports to prevent rigid body displacements. For a soil-supported system, all displacements of the joint on the structure centerline are specified to be zero. Consequently, the displacements obtained from the frame analysis of soil-supported systems must be realized to be relative values only.

PART VI: COMPUTER PROGRAM

General Description of Program

112. The computer program--CUFRAM--which implements the foregoing procedures is written in the FORTRAN language for execution on computer systems employing word lengths equivalent to 15 decimal digits. Calculations during the equilibrium analysis are not particularly sensitive to computer word length. However, evaluation of component stiffness matrices and solution of the simultaneous equations in the frame analysis phase may require double precision computations for machines with word lengths of fewer than 15 decimal digits.

113. The program is written for operation in a time-sharing environment. Although program prompts must be answered interactively from the user terminal, the experienced user will take advantage of the permanent file capabilities provided for input and output of data. Because the output from the program may be extensive, it may be advantageous for the user to direct output to a permanent file and to recover the output data with a high speed printer after execution of the program is terminated.

Input Data

114. Input data (Guide for Data Input, Appendix A) may be supplied from the user terminal or from a predefined data file. When data are supplied during execution from the terminal, program prompts are provided to indicate the type and amount of data to be provided.

115. Input data are divided into sections and subsections. This is shown as Figure 33.

116. Data sections I, II, IIIA, and VA need only be entered once since these data apply to the entire structure. Other data sections are interpreted as applying to the rightside or leftside of the structure. If symmetric conditions exist for both sides of the structure, the data are designated as being applicable to both sides. In this case, data need only be entered for the rightside and the program automatically generates mirror image data for the leftside. When different conditions exist for the two sides, data are entered for the rightside first and immediately followed by the description for the leftside.

I. Heading*
II. Mode of Operation*
III. Structure Data*
    A. Floor Data*
    B. Base Data*
    C. Stem Data*
    D. Culvert Data**
    E. Void Data**
        1. Void Tie Data**
IV. Backfill Data**
    A. Soil Layer Data, or †
    B. Backfill Soil Pressure Data †
V. Base Reaction Data*
    A. Soil Data, or †
    B. Pile Data †
        1. Layout Data*
        2. Pile/Soil Properties, or †
        3. Pile Head Stiffness Matrices †
        4. Batter Data**
        5. Allowables Comparison Data**
VI. Water Data**
    A. External Water Data**
        1. Water Elevations, or †
        2. Water Pressure Data †
    B. Uplift Water Data**
        1. Water Elevations, or †
        2. Water Pressure Data †
    C. Internal Water Data**
VII. Additional Load Data**
    A. Exterior Stem Loads**
        1. Distributed Loads
        2. Concentrated Loads
    B. Interior Stem Loads**
        1. Distributed Loads
        2. Concentrated Loads
    C. Top Stem Loads**
        1. Distributed Loads
        2. Concentrated Loads
    D. Floor Loads**
        1. Distributed Loads
        2. Concentrated Loads
    E. Base Loads**
        1. Distributed Loads
        2. Concentrated Loads

---

* Data section is required.
** Optional data may be omitted entirely.
† One of the two data subsections is required.

Figure 33. Sections and subsections of input data

117. During the input phase, from a file or from the user terminal, data values are checked for consistency of dimensions and completeness. If an error is encountered during input from a file, the user is notified and execution of that problem is terminated. If an error is detected during entry from the terminal, the user is offered the opportunity to revise the last entry which produced the error.

Data Editing

118. After the input phase is completed, from a file or from the terminal, the user is offered the opportunity to edit (revise) the current input data. Any data section or subsection selected for editing must be entered in its entirety.

Data File Creation

119. After any data entry from the terminal, initial or after editing, the user is offered the opportunity to save the existing input data in a permanent file in data file format. Because the program prompts for entry from the terminal are lengthy, an experienced user will usually find it more efficient to perform editing of an input file externally from the program.

Output Data

120. Output data may be directed to a permanent file, to the user terminal, or to both simultaneously. These sections of output are available.

Echoprint of input data

121. The echoprint of input data is a tabular presentation of numerical [illegible] including appropriate headings and units. This section of the output is [illegible]

[illegible] equilibrium analysis

[illegible] section presents pressures generated by the program or [illegible] input at key points on the structure, resultants of loads on [illegible] ture, and net resultants of all loads.

[illegible] data regarding the 2-D frame model developed

by the program in the frame analysis mode. Included are data defining the rigid blocks, coordinates of the joints of the model, member connectivity, member dimensions, and pile stiffness coefficients if a pile foundation is present.

Results of frame analysis

124. This section incorporates the calculated displacements for each joint in the structure, forces at the ends of the flexible length for each member, displacements and pile head forces for a pile-supported structure, and results of the pile allowables comparisons. (Appendix A--discussion of allowables comparisons performed for piles.)

Detailed member forces

125. Following the frame analysis, the user may obtain a tabulation giving the variation of axial force, shear force, and bending moment within any member of the structure selected. This section of the output is optional.

Program verification

126. The pressures (backfill, water, soil base pressures) generated by the program have been verified by hand computations for a variety of systems. Wherever possible, the results (deflection, axial force, shear force, and bending moment) of the frame analysis have been calculated by other processes for comparison. For example, the internal forces at the juncture of the base slab and stem face for a soil-supported structure can be obtained from a static analysis. Similarly, deflections for the section of the base slab from the chamber centerline to the juncture of the base slab and stem face for a soil-supported system can be obtained from classical beam analysis. For indeterminate systems (types 2 and 3 monoliths or pile-supported structure), solutions have been obtained using the general-purpose computer system GTSTRUDL. Results using GTSTRUDL for several of the example solutions presented in Part VII are given in Appendix B of this report.

PART VII: EXAMPLE SOLUTIONS

127. The examples presented below are intended only to illustrate the use of the program and are not to be interpreted as a guide for application of the program.

Example 1--Type 1 Monolith

128. The symmetric, soil-supported system is shown in Figure 34. All soil and water data were provided by elevations and unit weights. The additional upward distributed load on the base might represent the effects of seepage parallel to the longitudinal axis of the structure.

Data input

129. Input data were entered from the terminal during execution as shown in Figure 35. The echoprint of input data (optional), Figure 36, provides a tabulation of the input data with appropriate labels and units. A plot of input geometry generated by the program is included in Figure 36. Following successful data entry, terminal input was saved in a file. The input file generated by the program shown in Figure 37 was retrieved following termination of the run. Because the system is symmetric, only the right side of the structure need be described.

Results of equilibrium analysis

130. The results of the equilibrium analysis are shown in Figure 38. Backfill soil and water data have been converted to pressures as shown in Section IIA of this figure. These pressures are determined at the location of changes in the geometry of the structure, at the elevations of soil layer boundaries, and at ground-water elevation. When a discontinuity in pressure occurs (e.g., at soil layer boundaries), two values of pressure at that elevation are given, one immediately above the elevation and one immediately below. In this case, the two values given at elevation 44 are the result of the horizontal top surface of the heel: the first for the point nearer the chamber centerline, and the second for the point at the end of the heel. Otherwise, the pressures vary linearly between successive elevations. Note that groundwater pressures do not affect the upward sloping section of the base. A plot of backfill and external water pressures generated by the program is included in Figure 38.

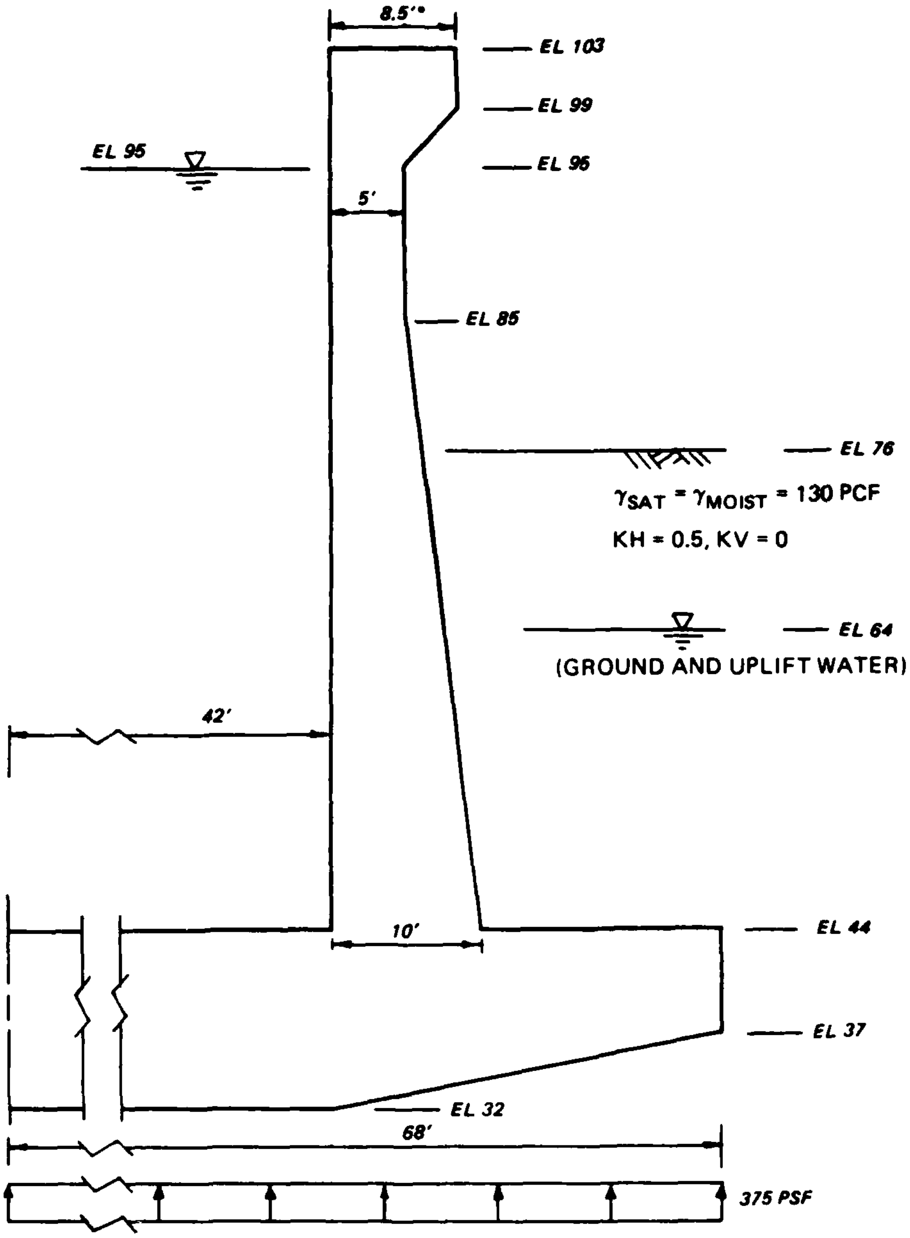


Figure 34. System for Example 1

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

```
     PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
     DATE: 09/02/86                                        TIME: 15:47:53

     ARE INPUT DATA TO BE PROVIDED FROM A DATA FILE
     CONTAINING DATA FOR A SEQUENCE OF PROBLEMS?
     ENTER 'YES' OR 'NO'.
? N

    ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
    ENTER 'TERMINAL' OR 'FILE'.
? T
     ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
     ENTER 2 HEADING LINES.
? EXAMPLE 1 - TYPE 1 MONOLITH
? SYMMETRIC SOIL-FOUNDED STRUCTURE
     ENTER METHOD OF ANALYSIS ('EQUIL' OR 'FRAME').
? F
     ENTER RIGID LINK FACTOR (0.LE.SHRINK.LE.ONE).
? 0.75
     ENTER STRUCTURE CONTROL DATA:
          <-------CONCRETE PROPERTIES------->
          MODULUS OF       POISSON'S     UNIT       THICKNESS
          ELASTICITY         RATIO      WEIGHT       OF SLICE
            (PSI)        (0<PR<0.5)     (PCF)         (FT)
? 3.0E6 0.2 150 1
     ENTER STRUCTURE FLOOR DATA:
          WIDTH     ELEVATION     FILLET
           (FT)        (FT)        (FT)
? 42 44 0
     ENTER RIGHTSIDE BASE DATA (1 OR 2 POINTS):
         <--------FIRST POINT-------->       <-------SECOND POINT-------->
         DISTANCE FROM       ELEVATION       DISTANCE FROM       ELEVATION
         CHAMBER CL (FT)        (FT)         CHAMBER CL (FT)        (FT)
? 42 32 68 37
     ARE RIGHTSIDE AND LEFTSIDE BASE POINTS SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE STEM DATA, ONE POINT AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE STEM DATA.
          DIST. FROM
           STEM FACE      ELEVATION
             (FT)           (FT)
? 8.5 103
? 8.5 99
? 5 95
? 5 85
? 10 44
? 26 44
? E
     ARE LEFTSIDE AND RIGHTSIDE STEM DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
```

Figure 35. Terminal entry for Example 1 (Sheet 1 of 4)

```
      IS RIGHTSIDE CULVERT PRESENT?
      ENTER 'YES' OR 'NO'.
? N
      IS  LEFTSIDE CULVERT PRESENT?
      ENTER 'YES' OR 'NO'.
? N
      IS RIGHTSIDE STEM VOID PRESENT?  ENTER 'YES' OR 'NO'.
? N
      IS  LEFTSIDE STEM VOID PRESENT?  ENTER 'YES' OR 'NO'.
? N
      ARE RIGHTSIDE BACKFILL DATA TO BE PROVIDED?
      ENTER 'YES' OR 'NO'.
? Y
      ARE BACKFILL EFFECTS PROVIDED BY SOIL DATA OR A PRESSURE DISTRIBUTION?
      ENTER 'SOIL' OR 'PRESSURE'.
? S
      ENTER NUMBER OF RIGHTSIDE SOIL LAYERS (1 TO 5).
? 1
      ENTER DATA FOR 1 RIGHTSIDE SOIL LAYERS, ONE LINE PER LAYER:
      ELEVATION AT    SOIL UNIT WEIGHTS       <----SOIL COEFFICIENTS---->
      TOP OF LAYER    SATURATED   MOIST       HORIZ PRESS    SHEAR STRESS
          (FT)          (PCF)     (PCF)       TOP  BOTTOM    TOP   BOTTOM
? 76 130 130 .5 .5 0 0
      ENTER RIGHTSIDE SURCHARGE (PSF).
? 0
      ARE LEFTSIDE AND RIGHTSIDE BACKFILL CONDITIONS SYMMETRIC?
      ENTER 'YES' OR 'NO'.
? Y
      IS BASE REACTION PROVIDED BY SOIL OR PILES?
      ENTER 'SOIL' OR 'PILES'.
? S
      ENTER BASE REACTION DISTRIBUTION TYPE:
      'UNIFORM', 'TRAPEZOIDAL', 'RECTANGULAR', OR 'INPUT'.
? U
      ARE WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO'.
? Y
      ENTER WATER UNIT WEIGHT (PCF).
? 62.5
      ARE RIGHTSIDE EXTERNAL WATER DATA TO BE ENTERED?
      ENTER 'YES' OR 'NO'.
? Y
      ARE RIGHTSIDE EXTERNAL WATER EFFECTS TO BE PROVIDED BY ELEVATION DATA OR
      INPUT PRESSURE DATA?  ENTER 'ELEVATIONS' OR 'PRESSURES'.
? E
      ENTER RIGHTSIDE GROUND-WATER ELEVATION (FT).
? 64
      ENTER RIGHTSIDE SURCHARGE ELEVATION (FT) OR 'NONE'.
? N
      ARE LEFTSIDE AND RIGHTSIDE EXTERNAL WATER DATA SYMMETRIC?
      ENTER 'YES' OR 'NO'.
? Y
      ARE UPLIFT WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO.'
? Y
      ARE UPLIFT WATER EFFECTS TO BE PROVIDED BY WATER ELEVATIONS OR BY
      A PRESSURE DIAGRAM?  ENTER 'ELEVATIONS' OR 'PRESSURES'.
? E
```

Figure 35. (Sheet 2 of 4)

```
     ENTER UPLIFT WATER ELEVATIONS (FT)
          LEFTSIDE       RIGHTSIDE
? 64 64
     ARE INTERNAL WATER DATA TO BE ENTERED?  ENTER 'YES' OR 'NO'.
? Y
     ENTER WATER ELEVATION IN CHAMBER (FT).
? 95
     ARE ADDITIONAL LOAD DATA TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ADDITIONAL LOADS ON EXTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON EXTERIOR FACE OF  LEFTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON INTERIOR FACE OF RIGHTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON INTERIOR FACE OF  LEFTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON TOP OF RIGHTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON TOP OF  LEFTSIDE STEM TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON  LEFTSIDE OF CHAMBER FLOOR TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER DATA FOR CONCENTRATED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
     ENTER 'END' WHEN FINISHED WITH CONCENTRATED LOADS.
          DIST. FROM     HORIZONTAL      VERTICAL
          CHAMBER CL.    CONC. LOAD     CONC. LOAD
             (FT)           (PLF)          (PLF)
? E
     ENTER DATA FOR DISTRIBUTED LOADS ON RIGHTSIDE OF STRUCTURE BASE.
     ENTER 'END' WHEN FINISHED WITH DISTRIBUTED LOADS.
          DIST. FROM     HORIZONTAL      VERTICAL
          CHAMBER CL.    DIST. LOAD     DIST. LOAD
             (FT)           (PSF)          (PSF)
? 0 0 -375
? 68 0 -375
? E
     ARE LOADS ON LEFTSIDE AND RIGHTSIDE OF STRUCTURE BASE SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
```

Figure 35. (Sheet 3 of 4)

```
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? F
     ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CUEX1O
     DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'.
      Y
     ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? CUEX1I
     INPUT COMPLTE.
     DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CUEX1O', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F
     DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? Y
     EQUILIBRIUM ANALYSIS COMPLETE.
     DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT TO PLOT FRAME MODEL?
     ENTER 'YES' OR 'NO'.
? Y
     DEVELOPMENT OF FRAME MODEL COMPLETE.
     DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
     ENTER 'YES' OR 'NO'.
? Y
     DETAILED MEMBER FORCES ARE AVAILABLE FOR
     RIGHTSIDE MEMBERS 1 THROUGH  4
     ENTER LIST OF MEMBER NUMBERS, 'ALL', OR 'NONE'.
? A
     DO YOU WANT TO PLOT BASE AXIAL, SHEAR, AND MOMENT DIAGRAMS?
     ENTER 'YES' OR 'NO'.
? Y
     DO YOU WANT INDIVIDUAL MEMBER PLOTS?
     ENTER 'YES' OR 'NO'.
? Y
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
     ENTER 'YES' OR 'NO'.
? N
     DO YOU WANT TO MAKE ANOTHER 'CUFRAM' RUN? ENTER 'YES' OR 'NO'.
? N
     ********** NORMAL TERMINATION **********
END OF FILE
```

Figure 35. (Sheet 4 of 4)

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/03/86                                   TIME: 10:56:35

I.--HEADING
  'EXAMPLE 1 - TYPE 1 MONOLITH
  'SYMMETRIC SOIL-FOUNDED STRUCTURE

                ****************
                *  INPUT DATA  *
                ****************

II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR =         .75

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =     .20
     UNIT WEIGHT OF CONCRETE            =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    1.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      42.00 (FT)
     FLOOR ELEVATION   =      44.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CHAMBER CL        ELEVATION
          (FT)             (FT)
          42.00            32.00
          68.00            37.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE        ELEVATION
          (FT)             (FT)
           8.50           103.00
           8.50            99.00
           5.00            95.00
           5.00            85.00
          10.00            44.00
          26.00            44.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

a. Echoprint (Continued)

Figure 36. Input data for Example 1 (Sheet 1 of 4)

III.E.--CULVERT DATA
NONE

III.F.--VOID DATA
NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
76.00	130.0	130.0	.500	.500	0.000	0.000

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

REACTION PROVIDED BY UNIFORM SOIL PRESSURE DISTRIBUTION

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND-WATER ELEVATION = 64.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 64.00 (FT)

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 95.00 (FT)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

a. (Continued)

Figure 36. (Sheet 2 of 4)

VII.C.1--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE

CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA

DIST. FROM CHAMBER CL (FT)	HORIZONTAL LOAD (PSF)	VERTICAL LOAD (PSF)
0.00	0.00	-375.00
68.00	0.00	-375.00

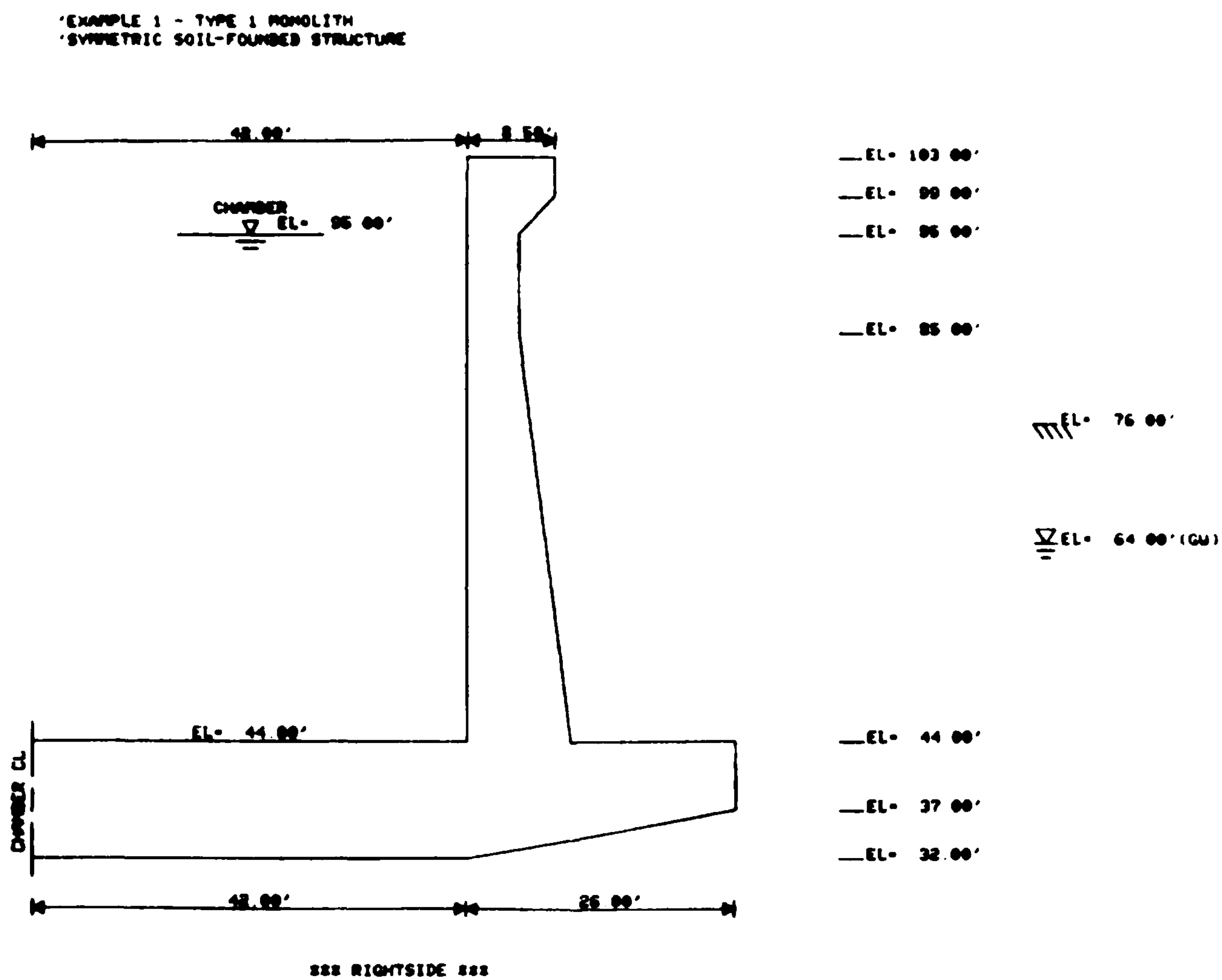
VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE

CONCENTRATED LOAD DATA
NONE

DISTRIBUTED LOAD DATA
SYMMETRIC WITH RIGHTSIDE

a. (Concluded)

Figure 36. (Sheet 3 of 4)



b. Plot of input geometry

Figure 36. (Sheet 4 of 4)

```
***** INPUT FILE FOR EXAMPLE1 GENERATED BY CUFRAM *****


1000 'EXAMPLE 1 - TYPE 1 MONOLITH
1010 'SYMMETRIC SOIL-FOUNDED STRUCTURE
1020 METHOD FR        .75
1030 STRUCTURE   3.00E+06        .20     150.00      1.00
1040 FLOOR          42.00      44.00       0.00
1050 BASE  BOTH                42.00      32.00      68.00     37.00
1060 STEM  BOTH         6
1070        8.50   103.00       8.50      99.00       5.00     95.00
1080        5.00    85.00      10.00      44.00      26.00     44.00
1090 BACKFILL  BOTH      SOIL         1       0.00
1100       76.00   130.00     130.00        .50        .50      0.00      0.00
1110 REACTION SOIL UNIFORM
1120 WATER            62.5
1130 EXTERNAL  BOTH      ELEVATION        64.00
1140 UPLIFT ELEVATION          64.00      64.00
1150 INTERNAL       95.00
1160 LOADS  BOTH     BASE
1170 DIST    2        0.00       0.00    -375.00      68.00       0.00   -375.00
1180 FINISH
```

Figure 37. CUFRAM generated input file for Example 1

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/03/86 TIME: 10:56:35

I.--HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* RESULTS OF EQUILIBRIUM ANALYSIS *
****

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE	--------->		GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
103.000	0.	0.	0.	0.
99.000	0.	0.	0.	0.
95.000	0.	0.	0.	0.
85.000	0.	0.	0.	0.
76.000	0.	0.	0.	0.
64.000	1.5600E+03	7.8000E+02	0.	0.
44.000	2.9100E+03	1.4550E+03	0.	1.2500E+03
44.000	2.9100E+03	1.4550E+03	0.	1.2500E+03
37.000	3.3825E+03	1.6913E+03	0.	1.6875E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

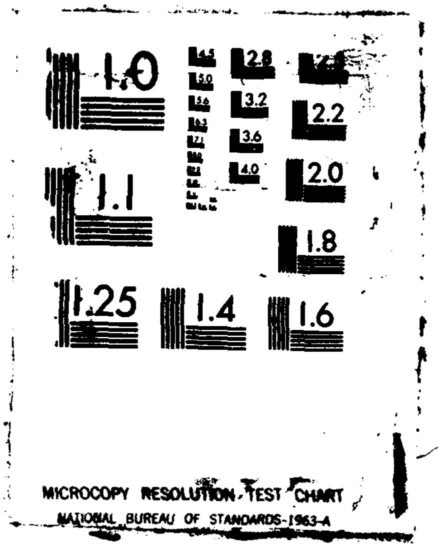
DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	3.3315E+03	2.0000E+03
42.000	3.3315E+03	2.0000E+03
68.000	3.3315E+03	1.6875E+03

a. Analysis results ...

Figure 38. Equilibrium ana...

AD-A182 553 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT 2/3
USER'S GUIDE: COMPUT..(U) DAWKINS (WILLIAM P)
STILLWATER OK W P DAWKINS APR 87 WES/TR/ITL-87-1

UNCLASSIFIED DACW39-83-M-3000 F/G 12/5 NL


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

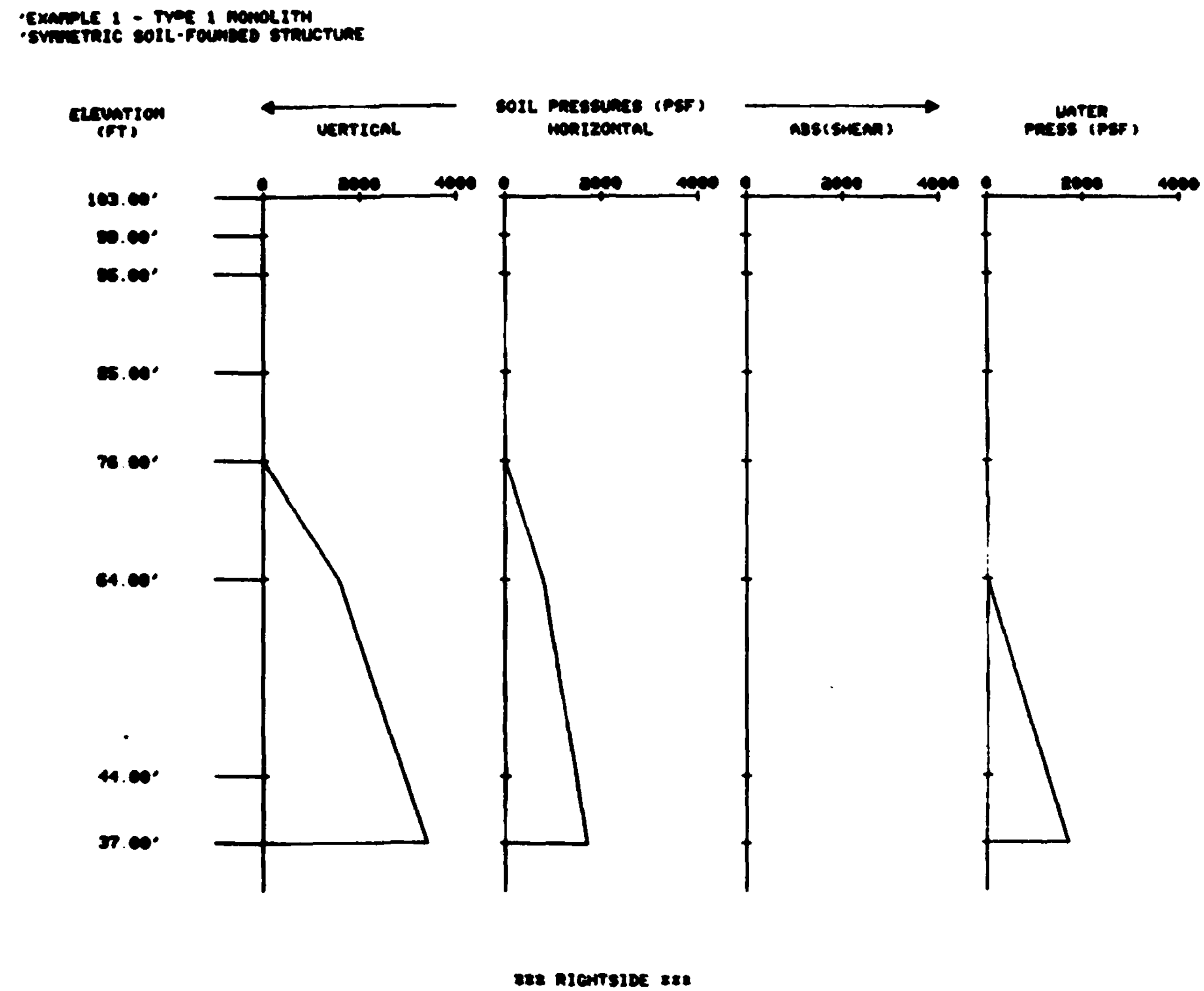
ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	3.8042E+04	5.3153E+04	-2.8533E+06
GROUND/SURCH WATER	2.2781E+04	2.1524E+04	-1.2325E+06
INTERNAL WATER	-8.1281E+04	1.3388E+05	-4.1932E+06
UPLIFT WATER	9.2187E+03	-1.3194E+05	4.2947E+06
SOIL-BASE REACT	0.	-2.2654E+05	7.7023E+06
BACKFILL ON BASE	8.8781E+03	0.	-8.4694E+04
ADDL BASE LOADS	0.	-2.5500E+04	8.6700E+05
CONCRETE		1.7543E+05	-6.4534E+06
TOTAL THIS SIDE	-2.3612E+03	0.	-1.9530E+06

III.--EFFECTS ON STRUCTURE LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

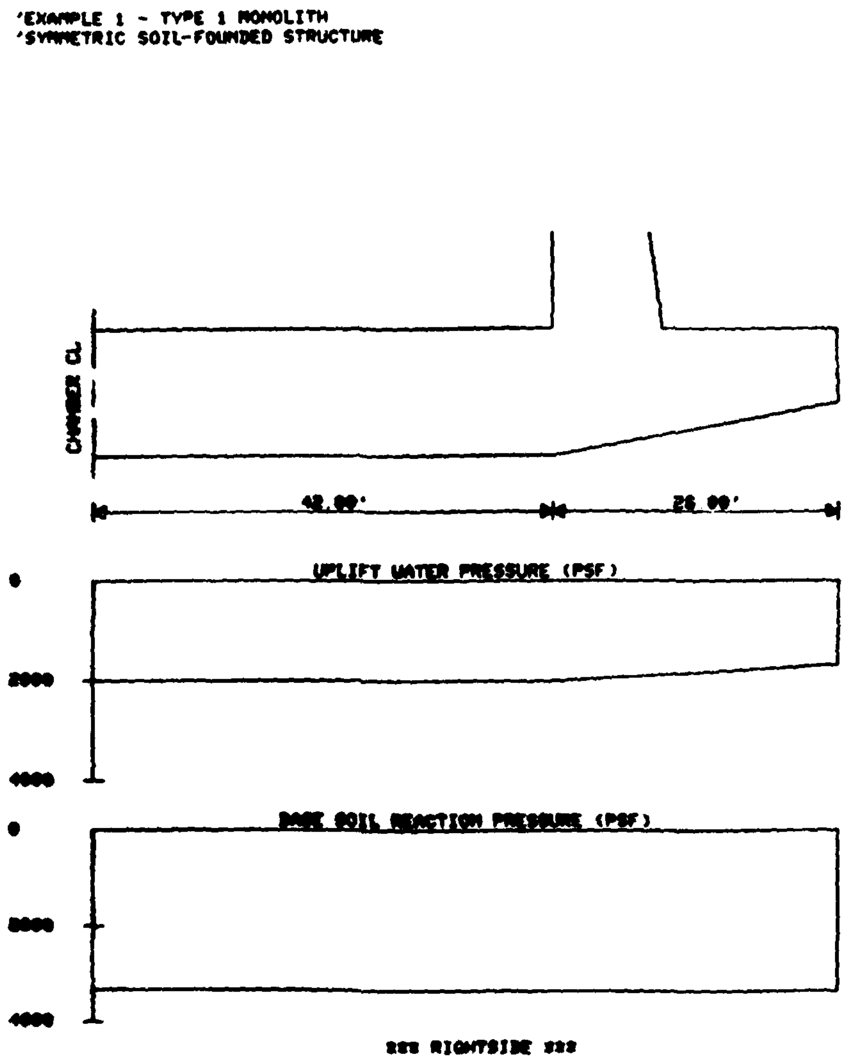
a. (Concluded)

Figure 38. (Sheet 2 of 4)



b. Backfill and external water pressures plot

Figure 38. (Sheet 3 of 4)



c. Base soil reaction and uplift water pressure

Figure 38. (Sheet 4 of 4)

131. Pressures on the base, Section IIB of Figure 38, consist of soil reaction pressure developed by the program to equilibrate all vertical loads according to the prescribed "uniform" distribution as well as uplift water pressures. Locations of pressures are given by distance (right or left) from the chamber centerline. When a discontinuity in pressure exists (e.g., for a prescribed "rectangular" base pressure distribution), two values are given for that location, the first being the value nearer the chamber centerline. A plot of base soil reaction and uplift water pressure is included in Figure 38.

132. Resultants of all applied loads and generated base reaction are given in Section IIC of Figure 38. Because the structure is symmetric, mirror images of the rightside forces act on the leftside of the structure. In this case, the net resultants, Section IV of Figure 38, are identically zero. Had the system been unsymmetric, base friction, base shear, and/or vertical stem shear would have been necessary to produce total equilibrium. For a pile-supported structure, any unbalanced total (net) resultants appearing in Figure 38, Section IV would be resisted by the piles.

133. If an equilibrium analysis had been specified, execution of the problem would cease when the equilibrium analysis had been completed. The user would then be offered the opportunity to edit existing input data or to make another run with new data.

Frame model data

134. Data for the plane frame model developed by the program are shown in Figure 39. Included are the defining coordinates of the rigid blocks associated with this type of monolith, the locations of the joints in the model, and the dimensions of the frame members. Note that the flexible lengths of the members extend into the rigid blocks due to the rigid link factor equal to 0.75. A plot of the frame model is shown in Figure 39.

Frame analysis

135. Results of the frame analysis are shown in Figure 40. Included are the displacements of the joints of the model, Section IIA, and the forces acting on the ends of the flexible length of each member parallel and perpendicular to the flexible member centerline. Pile head forces and results of pile allowables comparisons would be contained in this tabulation for a pile-supported structure (Example 2). A plot of axial, shear, and bending forces throughout the base is shown in Figure 40.

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/03/86 TIME: 10:56:35

I.--HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* FRAME MODEL DATA *
****

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 1 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

		<---------------		CORNER LOCATIONS		--------------->		
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	42.00	42.00	52.00	52.00	52.00	42.00	46.85
	ELEVATION	32.00	44.00	44.00	44.00	33.92	32.00	38.47
6	X-COORD.	42.00	42.00	50.50	50.50	47.00	47.00	45.90
	ELEVATION	95.00	103.00	103.00	99.00	95.00	95.00	99.31

II.B.--JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	38.00000
2	46.85482	38.46881
3	68.00000	40.50000
4	44.50000	85.00000
5	45.89617	99.30601

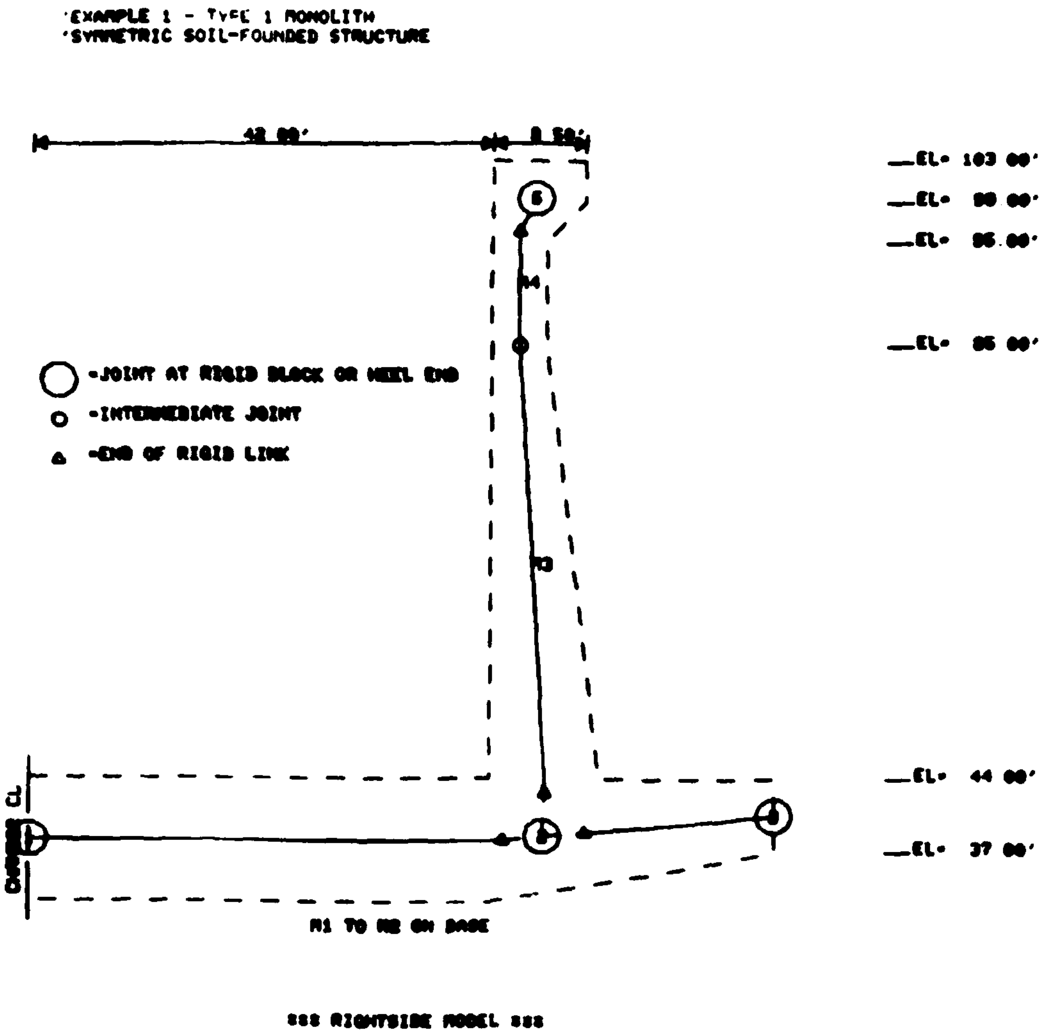
II.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	38.00	43.21	38.00	12.00	12.00
2	2	3	50.71	38.84	68.00	40.50	10.08	7.00
3	2	4	47.08	42.62	44.50	85.00	10.00	5.00
4	4	5	44.50	85.00	44.50	96.08	5.00	5.00

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

a. Model data

Figure 39. Plane frame model for Example 1 (Continued)



b. Frame model plot

Figure 39. (Concluded)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/03/86 TIME: 10:56:36

I.--HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

****
* RESULTS OF FRAME ANALYSIS *
****

II.--STRUCTURE DISPLACEMENTS
II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	38.00	0.	0.	0.
2	46.85	38.47	-5.850E-04	3.263E-02	-1.211E-03
3	68.00	40.50	-2.956E-03	5.823E-02	-1.211E-03
		***** STEM JOINTS *****			
4	44.50	85.00	-7.801E-02	2.879E-02	-1.899E-03
5	45.90	99.31	-1.055E-01	3.156E-02	-1.936E-03

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

III.--FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

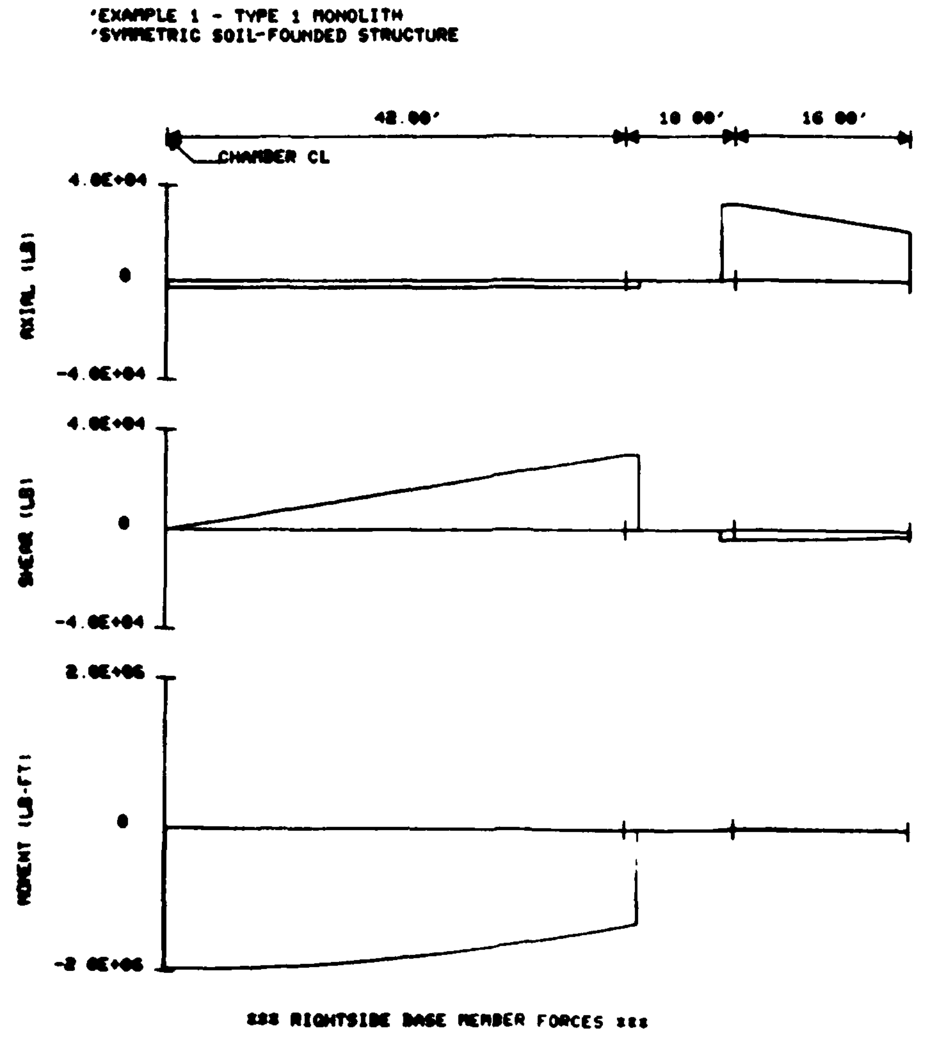
III.A.--RIGHTSIDE MEMBERS - TYPE 1 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

MEM NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	38.00	-2.361E+03	0.	-1.967E+06
	43.21	38.00	-2.361E+03	-3.020E+04	-1.296E+06
2	50.71	38.84	3.192E+04	-3.863E+03	8.844E+03
	68.00	40.50	2.120E+04	2.038E+03	-2.751E+03
		***** STEM MEMBERS *****			
3	47.08	42.62	7.330E+04	3.736E+04	-9.868E+05
	44.50	85.00	1.681E+04	-2.106E+03	-2.319E+04
4	44.50	85.00	1.665E+04	3.125E+03	-2.319E+04
	44.50	96.08	9.150E+03	0.	-1.278E+04

III.B.-- LEFTSIDE MEMBERS - TYPE 1 MONOLITH
SYMMETRIC WITH RIGHTSIDE

a. Analysis results

Figure 40. Results of frame analysis for Example 1 (Continued)



b. Frame model plot

Figure 40. (Concluded)

Detailed member forces

136. Member internal forces are shown in Figure 41. These forces are components parallel and perpendicular to the member centerline. They are reported at the tenth points along the member, on either side of an applied concentrated load where a discontinuity in axial and/or shear force would occur at the face of each rigid block to which the member is attached. A plot of the internal forces for each member is included in Figure 41.

Termination

137. Following completion of all output, the user is again offered the opportunity to edit existing data, to run the program with new data, or to terminate execution. Any abnormal interruption of the program before the "normal termination" indicated may result in the loss of any generated output files.

138. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/03/86 TIME: 10:56:37

I.--HEADING
'EXAMPLE 1 - TYPE 1 MONOLITH
'SYMMETRIC SOIL-FOUNDED STRUCTURE

II.--MEMBER INTERNAL FORCES
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE THE LEFT END OF A SECTION UP OR TOWARD THE CHAMBER CENTERLINE.)
(POSITIVE BENDING MOMENT PRODUCES COMPRESSION ON THE TOP OF THE MEMBER OR ON THE SIDE OF THE MEMBER TOWARD THE CHAMBER CENTERLINE.)

II.A.--RIGHTSIDE MEMBERS - TYPE 1 MONOLITH

***** RIGHTSIDE MEMBER 1

DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
0.00	38.00	-2.361E+03	0.	-1.967E+06
4.32	38.00	-2.361E+03	3.107E+03	-1.960E+06
8.64	38.00	-2.361E+03	6.214E+03	-1.940E+06
12.96	38.00	-2.361E+03	9.321E+03	-1.907E+06
17.29	38.00	-2.361E+03	1.243E+04	-1.860E+06
21.61	38.00	-2.361E+03	1.553E+04	-1.799E+06
25.93	38.00	-2.361E+03	1.864E+04	-1.725E+06
30.25	38.00	-2.361E+03	2.175E+04	-1.638E+06
34.57	38.00	-2.361E+03	2.486E+04	-1.537E+06
38.89	38.00	-2.361E+03	2.796E+04	-1.423E+06
42.00	38.00	-2.361E+03	3.020E+04	-1.333E+06
43.21	38.00	-2.361E+03	3.020E+04	-1.296E+06

***** RIGHTSIDE MEMBER 2

DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
50.71	38.84	3.192E+04	-3.863E+03	8.844E+03
52.00	38.96	3.192E+04	-3.863E+03	3.853E+03
52.44	39.00	3.161E+04	-3.869E+03	3.666E+03
54.17	39.17	3.039E+04	-3.861E+03	2.782E+03
55.90	39.34	2.919E+04	-3.805E+03	1.717E+03
57.63	39.50	2.800E+04	-3.700E+03	5.589E+02
59.36	39.67	2.683E+04	-3.545E+03	-6.032E+02
61.09	39.84	2.567E+04	-3.342E+03	-1.681E+03
62.81	40.00	2.453E+04	-3.090E+03	-2.586E+03
64.54	40.17	2.340E+04	-2.788E+03	-3.230E+03
66.27	40.33	2.229E+04	-2.438E+03	-3.524E+03
68.00	40.50	2.120E+04	-2.038E+03	-3.381E+03

a. Internal forces (Continued)

Figure 41. Detailed member forces for Example 1 (Sheet 1 of 6)

***** RIGHTSIDE MEMBER 3

DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
47.08	42.62	7.330E+04	3.736E+04	-9.868E+05
47.00	44.00	7.330E+04	3.736E+04	-9.351E+05
46.83	46.86	6.763E+04	3.619E+04	-8.231E+05
46.57	51.09	5.969E+04	3.391E+04	-6.657E+05
46.31	55.33	5.232E+04	3.099E+04	-5.209E+05
46.05	59.57	4.553E+04	2.743E+04	-3.915E+05
45.79	63.81	3.932E+04	2.322E+04	-2.800E+05
45.53	68.05	3.369E+04	1.863E+04	-1.887E+05
45.28	72.29	2.868E+04	1.396E+04	-1.181E+05
45.02	76.52	2.427E+04	9.208E+03	-6.861E+04
44.76	80.76	2.034E+04	5.107E+03	-3.861E+04
44.50	85.00	1.681E+04	2.106E+03	-2.368E+04

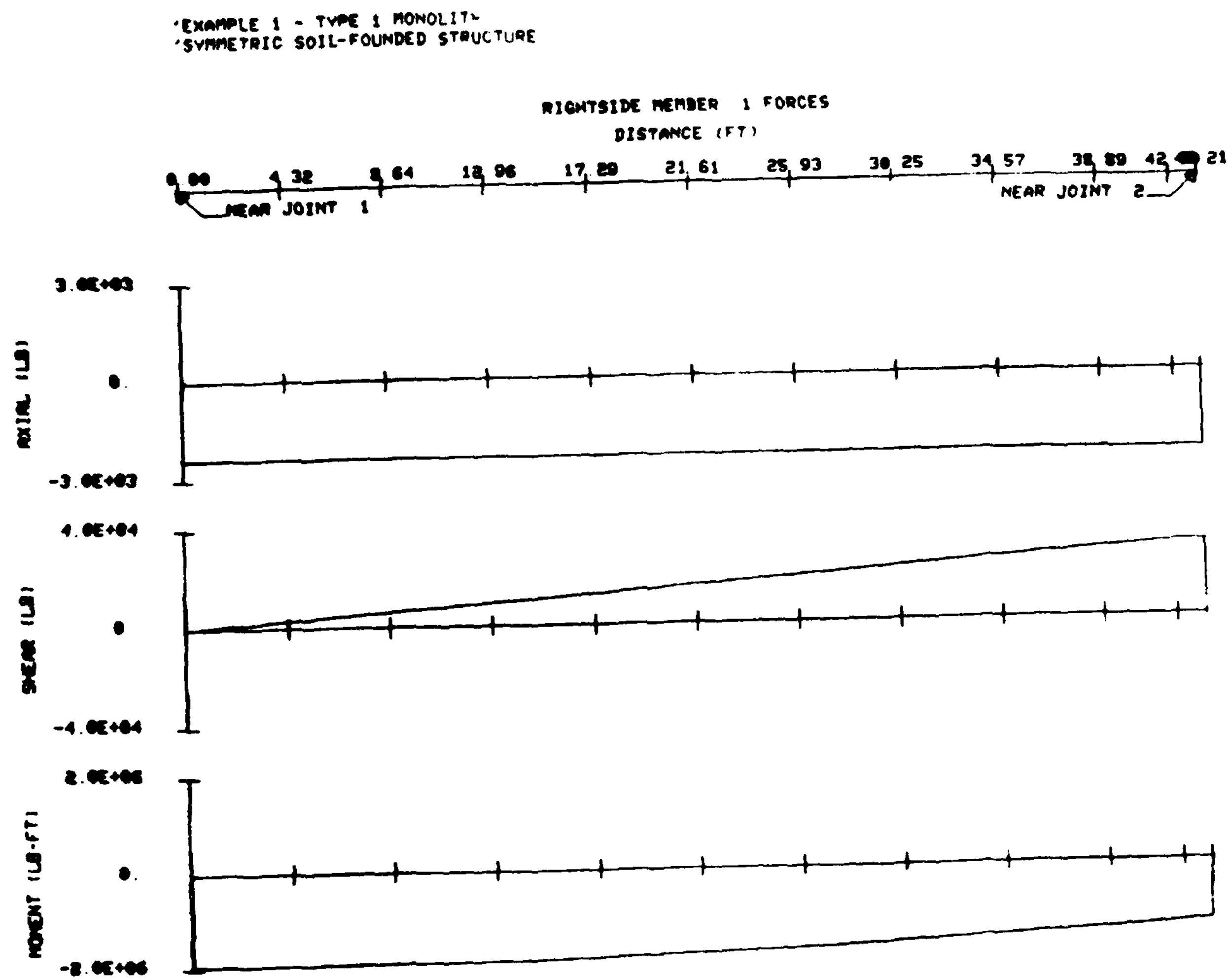
***** RIGHTSIDE MEMBER 4

DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LB OR LB-FT)-------> AXIAL	SHEAR	MOMENT
44.50	85.00	1.665E+04	3.125E+03	-2.319E+04
44.50	86.11	1.582E+04	2.471E+03	-2.010E+04
44.50	87.22	1.499E+04	1.894E+03	-1.769E+04
44.50	88.32	1.416E+04	1.393E+03	-1.588E+04
44.50	89.43	1.333E+04	9.693E+02	-1.457E+04
44.50	90.54	1.250E+04	6.221E+02	-1.370E+04
44.50	91.65	1.167E+04	3.516E+02	-1.317E+04
44.50	92.75	1.083E+04	1.577E+02	-1.289E+04
44.50	93.86	1.000E+04	4.053E+01	-1.279E+04
44.50	94.97	9.173E+03	3.032E-02	-1.278E+04
44.50	95.00	9.150E+03	9.939E-09	-1.277E+04
44.50	96.08	9.150E+03	9.939E-09	-1.277E+04

II.B.-- LEFTSIDE MEMBERS
SYMMETRIC WITH RIGHTSIDE MEMBERS

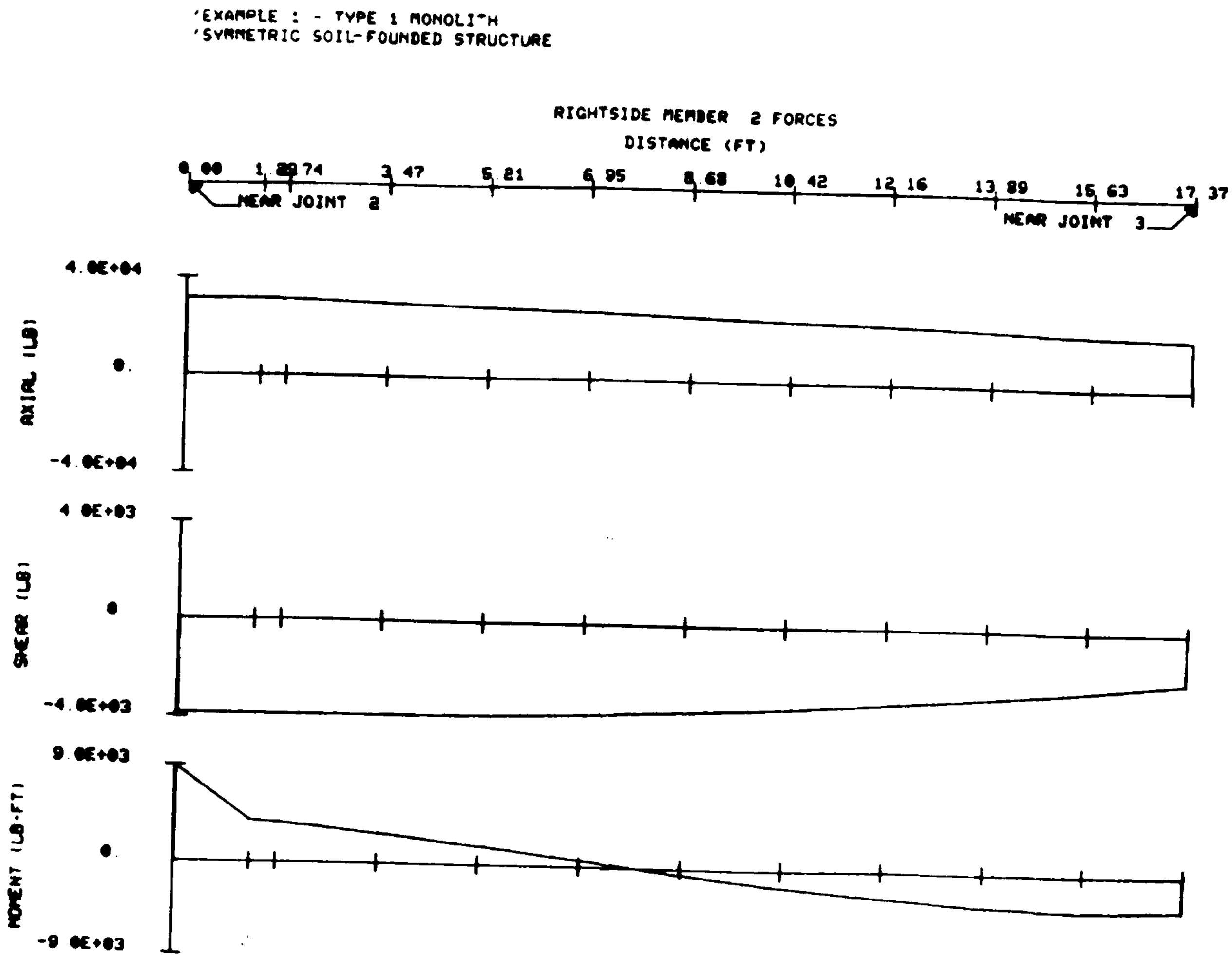
a. (Concluded)

Figure 41. (Sheet 2 of 6)



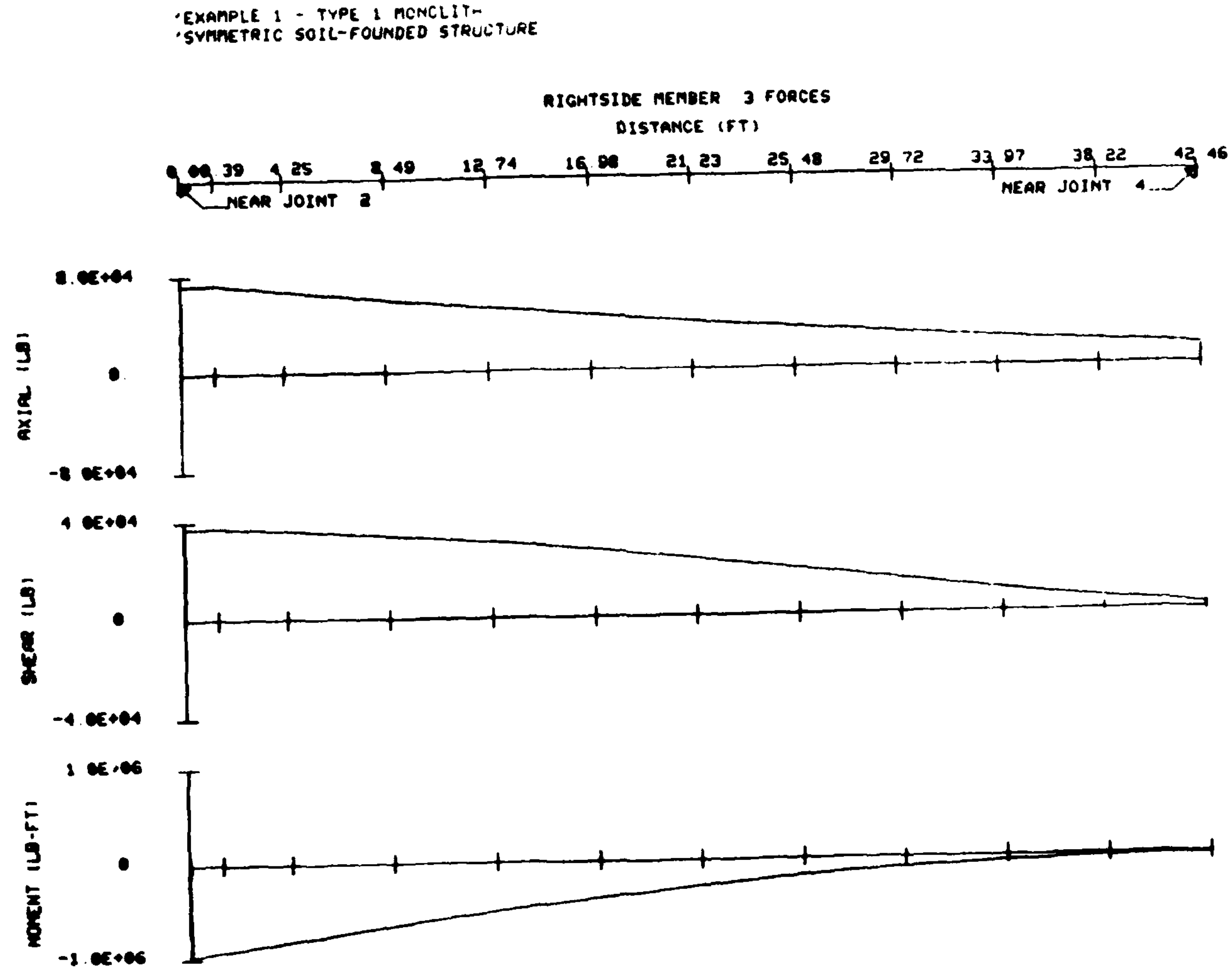
b. Plot for member 1 forces

Figure 41. (Sheet 3 of 6)



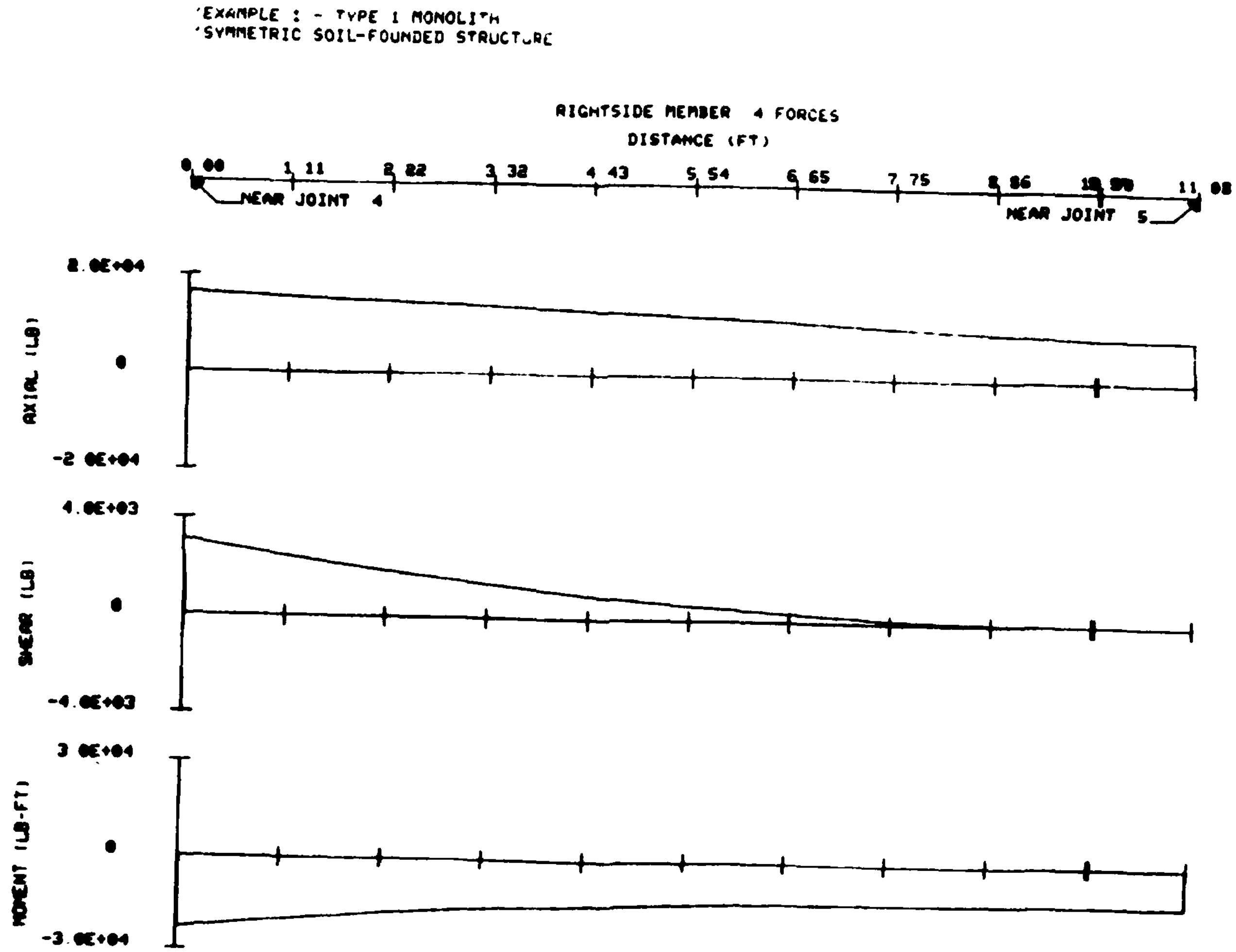
c. Plot for member 2 forces

Figure 41. (Sheet 4 of 6)



d. Plot for member 3 forces

Figure 41. (Sheet 5 of 6)



e. Plot for member 4 forces

Figure 41. (Sheet 6 of 6)

Example 2--Type 2 Monolith

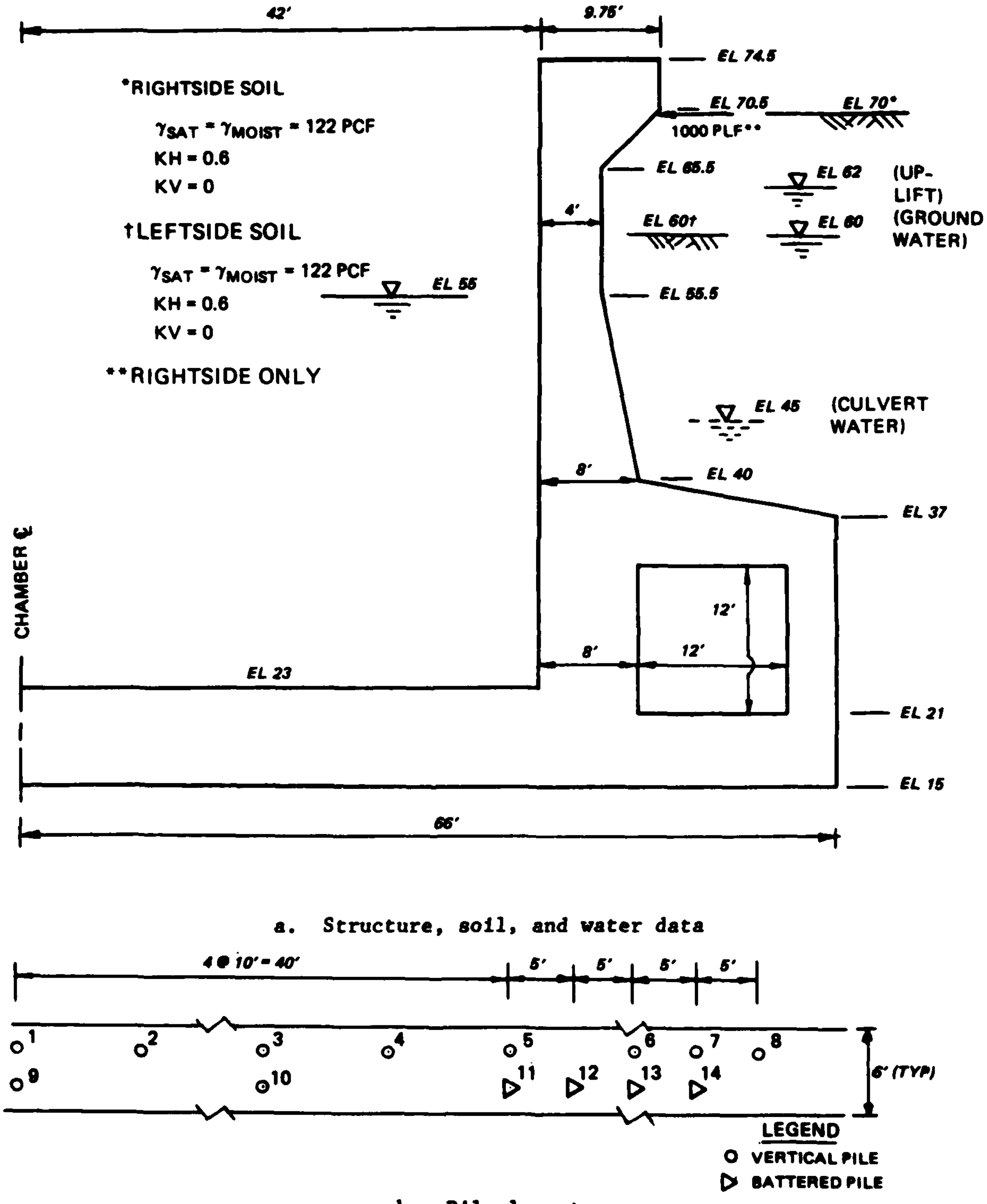
139. The right half of the symmetric structure is shown in Figure 42. Because the rightside and leftside backfill soils are at different elevations and due to unsymmetric additional loads, the entire system is unsymmetric. An equilibrium analysis was initially performed for a 6-ft thick slice of the soil-supported system. Example 2A is referred to in Figures 43, 44, and 45. A listing of the predefined input data file is shown in Figure 43 and an echoprint of input data is given in Figure 44. Results of the equilibrium analysis are shown in Figure 45. Note that equilibrium of the unsymmetric system was achieved by addition of friction on the base of the structure and by skewing of the nominally rectangular base reaction distribution.

140. Following the initial equilibrium analysis, the input data were edited to prescribe a frame analysis and to change from soil to pile supports as shown in Figure 46. Example 2B of the type 2 monolith is referred to in Figures 46, 47, 48, and 49. A listing of the input file for the new system generated by the program is shown in Figure 47. An echoprint of existing input data is given in Figure 48. Plots of rightside geometry are included.

141. Results of the equilibrium analysis are shown in Figure 49. The nonzero net resultants, due to unsymmetric loading, are resisted by the piles.

142. Frame model data generated by the program are shown in Figure 50. Note that joints along the base slab have been assigned at locations where one or more piles intersect the flexible portion of the structure. Piles which intersect the boundaries of the rigid blocks are assumed to be attached by rigid links to joints at the centroid of the rigid block. Plots of the frame model are included in Figure 50.

143. Results of the frame analysis are shown in Figure 51. The results include displacements of all joints in the model as well as member forces at the ends of the member flexible lengths. Pile head forces and displacements, parallel and perpendicular to the axis of the pile, are given for each pile on each side. Note that the pile layout data are symmetric and that two vertical piles (piles 1 and 9) are located on the centerline. The stiffness effects of each of these piles have been evaluated only once. However, forces and displacements of the two centerline piles have been reported with the results for each side. The results of pile allowables comparisons are presented for information purposes only. The program does not attempt to assess the effect



a. Structure, soil, and water data

b. Pile layout

Figure 42. System for Example 2

```
     PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
     DATE: 09/18/85                                      TIME: 15:07:21

     ARE INPUT DATA TO BE READ FROM TERMINAL OR FILE?
     ENTER 'TERMINAL' OR 'FILE'.
? f
     ENTER INPUT FILENAME (6 CHARACTERS MAXIMUM).
? cuex2i
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? f
     ENTER OUTPUT FILENAME (6 CHARACTERS MAXIMUM).
? cuex2a
     DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR 'NO'.
? n
     INPUT COMPLETE.
     DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? y
     DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CUEX2A', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f


     RESULTANT OF ALL HORIZONTAL LOADS IS    -2.25600E+05 (LBS).
     DO YOU WANT TO TERMINATE THIS PROBLEM, EQUILIBRATE HORIZONTAL LOADS BY
     FRICTION ON BASE OR EQUILIBRATE HORIZONTAL LOADS BY SHEAR IN BASE?
     ENTER 'TERMINATE', 'FRICTION', OR 'SHEAR'.
? f
```

Figure 43. Program execution and input file for Example 2A (Continued)

```
1000  'EXAMPLE 2A - TYPE 2 MONOLITH
1010  'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS
1020  'SOIL-FOUNDED STRUCTURE
1030 METHOD EQ
1040 STRUCTURE   3.00E+06        .20    150.00      6.00
1050 FLOOR          42.00      23.00      0.00
1060 BASE  BOTH                66.00     15.00
1070 STEM  BOTH            8
1080        9.75     74.50      9.75     70.50      4.00      65.50
1090        4.00     55.50      8.00     40.00     24.00      37.00
1100       24.00     21.00     24.00     21.00
1110 CULVERT  BOTH              8.00     12.00     21.00      12.00      0.00
1120 BACKFILL RIGHTSIDE SOIL       1       0.00
1130       70.00    122.00    122.00       .60       .60       0.00      0.00
1140 BACKFILL  LEFTSIDE SOIL       1       0.00
1150       60.00    122.00    122.00       .60       .60       0.00      0.00
1160 REACTION SOIL RECTANGULAR .5
1270 WATER            62.5
1280 EXTERNAL  BOTH      ELEVATION        60.00
1290 UPLIFT ELEVATION           62.00     62.00
1300 INTERNAL       55.00     45.00     45.00
1310 LOADS RIGHTSIDE STEM EXTERIOR
1320 CONC     1     70.00   1000.00      0.00
1330 FINISH
```

Figure 43. (Concluded)

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85                                   TIME: 15:07:41

I.--HEADING
  'EXAMPLE 2A - TYPE 2 MONOLITH
  'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS
  'SOIL-FOUNDED STRUCTURE

               ****************
               *  INPUT DATA  *
               ****************

II.--EQUILIBRIUM ANALYSIS ONLY

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =      .20
     UNIT WEIGHT OF CONCRETE            =  150.0    (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    6.00   (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      42.00 (FT)
     FLOOR ELEVATION   =      23.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CHAMBER CL       ELEVATION
         (FT)             (FT)
         66.00            15.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE       ELEVATION
          (FT)            (FT)
          9.75            74.50
          9.75            70.50
          4.00            65.50
          4.00            55.50
          8.00            40.00
         24.00            37.00
         24.00            21.00
         24.00            21.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

Figure 44. Echoprint of input data for Example 2A (Sheet 1 of 3)

```
III.E.--CULVERT DATA

  III.E.1.--RIGHTSIDE
   DISTANCE FROM STEM FACE TO INTERIOR SIDE =        8.00 (FT)
   CULVERT WIDTH                            =       12.00 (FT)
   ELEVATION AT CULVERT FLOOR               =       21.00 (FT)
   CULVERT HEIGHT                           =       12.00 (FT)
   CULVERT FILLET SIZE                      =        0.00 (FT)

  III.E.2.--LEFTSIDE
   SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA
   NONE


IV.--BACKFILL DATA

 IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE =      0.00 (PSF))
   ELEV                                <-PRESSURE COEFFICIENTS->
    AT     SATURATED    MOIST          HORIZONTAL       SHEAR
   TOP      UNIT WT.   UNIT WT.        TOP    BOT.     TOP    BOT.
   (FT)      (PCF)      (PCF)
   70.00     122.0      122.0          .600   .600     0.000 0.000

 IV.B.-- LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE =      0.00 (PSF))
   ELEV                                <-PRESSURE COEFFICIENTS->
    AT     SATURATED    MOIST          HORIZONTAL       SHEAR
   TOP      UNIT WT.   UNIT WT.        TOP    BOT.     TOP    BOT.
   (FT)      (PCF)      (PCF)
   60.00     122.0      122.0          .600   .600     0.000 0.000


V.--BASE REACTION DATA

   REACTION PROVIDED BY RECTANGULAR SOIL PRESSURE DISTRIBUTION
   FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE =      .50

VI.--WATER DATA
   WATER UNIT WEIGHT =  62.5 (PCF)

 VI.A.--EXTERNAL WATER DATA

  VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
   GROUND WATER ELEVATION    =     60.00 (FT)
   SURCHARGE WATER                  NONE

  VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
   SYMMETRIC WITH RIGHTSIDE
```

Figure 44. (Sheet 2 of 3)

```
  VI.B.--UPLIFT WATER DATA
     RIGHTSIDE UPLIFT WATER ELEVATION =     62.00 (FT)
     LEFTSIDE UPLIFT WATER ELEVATION  =     62.00 (FT)

  VI.C.--INTERNAL WATER DATA
     WATER ELEVATION IN CHAMBER            =     55.00 (FT)
     WATER ELEVATION IN RIGHTSIDE CULVERT =     45.00 (FT)
     WATER ELEVATION IN LEFTSIDE CULVERT  =     45.00 (FT)

VII.--ADDITIONAL LOAD DATA

  VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

    CONCENTRATED LOAD DATA
     ELEVATION    HORIZONTAL    VERTICAL
      AT LOAD        LOAD         LOAD
       (FT)          (PLF)        (PLF)
       70.00        1000.00        0.00

    DISTRIBUTED LOAD DATA
     NONE

  VII.A.2.--ADDITIONAL LOADS ON  LEFTSIDE EXTERNAL STEM FACE
     NONE

  VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
     NONE

  VII.B.2.--ADDITIONAL LOADS ON  LEFTSIDE INTERIOR STEM FACE
     NONE

  VII.C.1--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
     NONE

  VII.C.2--ADDITIONAL LOADS ON  LEFTSIDE STEM TOP
     NONE

  VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
     NONE

  VII.D.2.--ADDITIONAL LOADS ON  LEFTSIDE OF CHAMBER FLOOR
     NONE

  VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
     NONE

  VII.E.2.--ADDITIONAL LOADS ON  LEFTSIDE OF STRUCTURE BASE
     NONE
```

Figure 44. (Sheet 3 of 3)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 15:08:01

I.--HEADING
'EXAMPLE 2A - TYPE 2 MONOLITH
'UNSYMMETRIC SYSTEM DUE TO BACKFILL AND ADDITIONAL LOADS
'SOIL-FOUNDED STRUCTURE

```
**************************************
*  RESULTS OF EQUILIBRIUM ANALYSIS  *
**************************************
```

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE---------		--------->	GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
70.000	0.	0.	0.	0.
65.500	5.4900E+02	3.294CE+02	0.	0.
60.000	1.2200E+03	7.3200E+02	0.	0.
55.500	1.4878E+03	8.9265E+02	0.	2.8125E+02
55.000	1.5175E+03	9.1050E+02	0.	3.1250E+02
40.000	2.4100E+03	1.4460E+03	0.	1.2500E+03
37.000	2.5885E+03	1.5531E+03	0.	1.4375E+03
33.000	2.8265E+03	1.6959E+03	0.	1.6875E+03
23.000	3.4215E+03	2.0529E+03	0.	2.3125E+03
21.000	3.5405E+03	2.1243E+03	0.	2.4375E+03
15.000	3.8975E+03	2.3385E+03	0.	2.8125E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	7.9331E+02	2.9375E+03
42.000-	8.6465E+02	2.9375E+03
42.000+	3.0463E+03	2.9375E+03
50.000	3.0598E+03	2.9375E+03
62.000	3.0802E+03	2.9375E+03
66.000	3.0870E+03	2.9375E+03

Figure 45. Results of equilibrium analysis for Example 2A (Sheet 1 of 3)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	4.3648E+05	2.7818E+05	-1.0515E+07
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
SOIL-BASE REACT	-1.1280E+05	-6.5050E+05	2.9210E+07
ADDL EXT STEM LOADS	6.0000E+03	0.	2.8200E+05
CONCRETE		8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	5.1737E+05	4.6741E+04	6.1133E+05

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
65.500	0.	0.	0.	0.
60.000	0.	0.	0.	0.
55.500	2.6775E+02	1.6065E+02	0.	2.8125E+02
55.000	2.9750E+02	1.7850E+02	0.	3.1250E+02
40.000	1.1900E+03	7.1400E+02	0.	1.2500E+03
37.000	1.3685E+03	8.2110E+02	0.	1.4375E+03
33.000	1.6065E+03	9.6390E+02	0.	1.6875E+03
23.000	2.2015E+03	1.3209E+03	0.	2.3125E+03
21.000	2.3205E+03	1.3923E+03	0.	2.4375E+03
15.000	2.6775E+03	1.6065E+03	0.	2.8125E+03

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	7.9331E+02	2.9375E+03
42.000-	7.2197E+02	2.9375E+03
42.000+	2.9036E+03	2.9375E+03
50.000	2.8900E+03	2.9375E+03
62.000	2.8696E+03	2.9375E+03
66.000	2.8628E+03	2.9375E+03

Figure 45. (Sheet 2 of 3)

III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER
FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	2.1688E+05	1.4030E+05	-6.4746E+06
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
SOIL-BASE REACT	1.1280E+05	-6.0610E+05	2.5452E+07
CONCRETE		8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	5.1737E+05	-4.6741E+04	6.1133E+05

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = 0.
TOTAL VERTICAL = 0.
TOTAL MOMENT = 0.

NOTE: HORIZONTAL EQUILIBRIUM PROVIDED BY FRICTION ON BASE.

Figure 45. (Sheet 3 of 3)

```
    OUTPUT COMPLETE.
    DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
    ENTER 'YES' OR 'NO'.
? Y

     MAJOR DATA SECTIONS:
        1....HEADING
        2....METHOD OF ANALYSIS
        3....STRUCTURE DATA
        4....BACKFILL DATA
        5....BASE REACTION DATA
        6....WATER DATA
        7....ADDITIONAL LOAD DATA
     TO DELETE AN ENTIRE SECTION ENTER 'DELETE' BEFORE SECTION NUMBER.
     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 1
     ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
     ENTER 2 HEADING LINES.
? EXAMPLE 2B - TYPE 2 MONOLITHOF EXAMPLE 2A
? WITH PILE SUPPORT
     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 2
     ENTER METHOD OF ANALYSIS ('EQUIL' OR 'FRAME').
? F
     ENTER RIGID LINK FACTOR (0.LE.SHRINK.LE.ONE).
? 1
     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? 5
     CURRENT BASE REACTION IS PROVIDED BY SOIL.
     DO YOU WANT TO CHANGE TO PILE REACTION?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE LAYOUT DATA, ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE LAYOUT DATA.
          <-------START------>        STOP     <---STEP IN-->
          PILE      DIST. FROM        PILE      PILE      DIST.
           NO.      CHAMBER CL.        NO.       NO.      (FT)
                       (FT)
? 1 0
? 2 10 5 1 10
? 6 50 8 1 5
? 9 0
? 10 20
? 11 40 14 1 5
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE LAYOUT DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE/SOIL PROPERTIES TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? Y
END OF FILE
```

Figure 46. Data editing for Example 2B (Sheet 1 of 3)

```
     ARE RIGHTSIDE PILE/SOIL PROPERTIES TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE/SOIL PROPERTIES,  ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE/SOIL DATA.
          <--------------PILE PROPERTIES-------------->
  START    MOD.    SECT     MOM             AXIAL    HEAD    <-SOIL->  STOP  PILE
   PILE   ELAST    AREA   INERTIA  LENGTH   STIFF   FIXITY  <COEFFS>  PILE   NO.
    NO.   (PSI)  (SQIN)  (IN**4)    (FT)   COEFF    COEFF   SS1  SS2   NO.  STEP
? 1 2.9E7 21.4 729 45 1.3 0 0 10 14 1
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE/SOIL PROPERTIES DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE HEAD STIFFNESS MATRICES TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? N
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE BATTER DATA TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? Y
     ARE RIGHTSIDE BATTER DATA TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE BATTER DATA, ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE BATTER DATA.
          START                       STOP      PILE
          PILE         BATTER         PILE      NO.
           NO.        (FT/FT)          NO.      STEP
? 11 3 14 1
? E
     ARE LEFTSIDE AND RIGHTSIDE PILE BATTER DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE PILE ALLOWABLE DATA TO BE PROVIDED?
     ENTER 'YES' OR 'NO'.
? Y
     ARE RIGHTSIDE PILE ALLOWABLE DATA TO BE ENTERED?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER RIGHTSIDE PILE ALLOWABLE DATA, ONE LINE AT A TIME.
     ENTER 'END' WHEN FINISHED WITH RIGHTSIDE PILE ALLOWABLE DATA.
        <ALLOWABLE AXIAL FORCE>
 START  COMP  TENS  COMP  TENS  ALLOW  MOM   MAX   OVER STRESS  STOP  PILE
  PILE  ONLY  ONLY  WITH  WITH   BEND  MAG   MOM     FACTORS    PILE   NO.
   NO.              BM    BM     MOM   FACT  FACT  COMP  TENS    NO.  STEP
        (K)   (K)   (K)   (K)   (K-F)        (IN)
? 1 215 88 364 364 196 1 56.6 1.33 1.33 14 1
? E
```

Figure 46. (Sheet 2 of 3)

```
     ARE LEFTSIDE AND RIGHTSIDE PILE ALLOWABLE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ARE ALL PILE DATA SYMMETRIC?
     ENTER 'YES' OR 'NO'.
? Y
     ENTER SECTION NUMBER (1 TO 7) TO BE EDITED, 'FINISHED', OR 'HELP'.
? F
    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
    TO A FILE, TO BOTH, OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? F
    ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? CUEX2B
    DO YOU WANT TO EDIT INPUT DATA? ENTER 'YES' OR' NO'.
? N
    DO YOU WANT INPUT DATA SAVED IN A FILE? ENTER 'YES' OR 'NO'.
? Y
    ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? CUX2BI
    INPUT COMPLETE.
    DO YOU WANT TO PLOT INPUT DATA? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT TO CONTINUE SOLUTION? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT RESULTS WRITTEN TO YOUR TERMINAL, TO FILE 'CUEX2B', OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? F
    DO YOU WANT TO PLOT PRESSURES? ENTER 'YES' OR 'NO'.
? N
    EQUILIBRIUM ANALYSIS COMPLETE.
    DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT TO PLOT FRAME MODEL?
    ENTER 'YES' OR 'NO'.
? Y
    DEVELOPMENT OF FRAME MODEL COMPLETE.
    DO YOU WANT TO CONTINUE WITH FRAME SOLUTION? ENTER 'YES' OR 'NO'.
? Y
    DO YOU WANT DETAILED MEMBER FORCES OUTPUT?
    ENTER 'YES' OR 'NO'.
? N
    OUTPUT COMPLETE.
    DO YOU WANT TO EDIT INPUT DATA FOR THE PROBLEM JUST COMPLETED?
    ENTER 'YES' OR 'NO'.
? N
    DO YOU WANT TO MAKE ANOTHER 'CUFRAM' RUN? ENTER 'YES' OR 'NO'.
? N
    ********** NORMAL TERMINATION **********
```

Figure 46. (Sheet 3 of 3)

***** INPUT FILE FOR EXAMPLE 2B GENERATED BY CUFRAM *****

```
1000 'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
1010 'WITH PILE SUPPORT
1020 METHOD FR       1.00
1030 STRUCTURE   3.00E+06       .20    150.00      6.00
1040 FLOOR          42.00     23.00      0.00
1050 BASE  BOTH               66.00     15.00
1060 STEM  BOTH         8
1070         9.75    74.50      9.75     70.50      4.00     65.50
1080         4.00    55.50      8.00     40.00     24.00     37.00
1090       24.00     21.00     24.00     21.00
1100 CULVERT  BOTH             8.00     12.00     21.00     12.00      0.00
1110 BACKFILL RIGHTSIDE SOIL         1       0.00
1120       70.00    122.00    122.00       .60       .60      0.00      0.00
1130 BACKFILL  LEFTSIDE SOIL         1       0.00
1140       60.00    122.00    122.00       .60       .60      0.00      0.00
1150 REACTION PILES
1160 PILES  BOTH
1170 LAYOUT         1          0.00    1     1       0.00
1180 LAYOUT         2         10.00    5     1      10.00
1190 LAYOUT         6         50.00    8     1       5.00
1200 LAYOUT         9          0.00    9     1       0.00
1210 LAYOUT        10         20.00   10     1       0.00
1220 LAYOUT        11         40.00   14     1       5.00
1230 PROPS     1  2.90E+07   21.4   729.0   45.0    1.3 0.00   0.00  10.00 14  1
1240 BATTER        11          3.00   14     1
1250 ALLOW     1  215.   88.  364.  364.  196.   1.00  56.60   1.33   1.33 14  1
1260 WATER           62.5
1270 EXTERNAL  BOTH      ELEVATION       60.00
1280 UPLIFT ELEVATION         62.00     62.00
1290 INTERNAL        55.00     45.00     45.00
1300 LOADS RIGHTSIDE STEM EXTERIOR
1310 CONC     1      70.00   1000.00      0.00
1320 FINISH
```

Figure 47. CUFRAM generated input file for Example 2B

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85
                                                  TIME: 15:37:32
I.--HEADING
  'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
  'WITH PILE SUPPORT

                 ****************
                 *  INPUT DATA  *
                 ****************

II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR =        1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE   =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE        =     .20
     UNIT WEIGHT OF CONCRETE             =   150.0     (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE  =     6.00    (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH        =       42.00 (FT)
     FLOOR ELEVATION    =       23.00 (FT)
     FLOOR FILLET SIZE  =        0.00 (FT)

  III.C.--BASE DATA

   III.C.1.--RIGHTSIDE
    DISTANCE FROM
     CHAMBER CL        ELEVATION
        (FT)             (FT)
        66.00            15.00

   III.C.2.--LEFTSIDE
    SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

   III.D.1.--RIGHTSIDE
    DISTANCE FROM
     STEM FACE         ELEVATION
        (FT)             (FT)
        9.75             74.50
        9.75             70.50
        4.00             65.50
        4.00             55.50
        8.00             40.00
       24.00             37.00
       24.00             21.00
       24.00             21.00

   III.D.2.--LEFTSIDE
    SYMMETRIC WITH RIGHTSIDE.
```

a. Echoprint (Continued)

Figure 48. Input data for Example 2B (Sheet 1 of 6)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00 (FT)
CULVERT WIDTH	=	12.00 (FT)
ELEVATION AT CULVERT FLOOR	=	21.00 (FT)
CULVERT HEIGHT	=	12.00 (FT)
CULVERT FILLET SIZE	=	0.00 (FT)

III.E.2.--LEFTSIDE

SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA

NONE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
70.00	122.0	122.0	.600	.600	0.000	0.000

IV.B.-- LEFTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	HORIZONTAL BOT.	SHEAR TOP	SHEAR BOT.
60.00	122.0	122.0	.600	.600	0.000	0.000

V.--BASE REACTION DATA

V.A.--RIGHTSIDE PILE DATA

V.A.1.--PILE LAYOUT DATA

<------START-----> PILE NO.	DIST. FROM CHAMBER CL (FT)	STOP PILE NO.	PILE NO. STEP	STEP IN CL DIST. (FT)
1	0.00	1	1	0.00
2	10.00	5	1	10.00
6	50.00	8	1	5.00
9	0.00	9	1	0.00
10	20.00	10	1	0.00
11	40.00	14	1	5.00

V.A.2.--PILE PROPERTIES

<-----START PILE NO.	MODULUS OF ELASTICITY (PSI)	SECT AREA (SQIN)	MOMENT OF INERTIA (IN**4)	LENGTH (FT)	AXIAL COEFF	HEAD FIXITY ----->	STOP PILE NO.	PILE NO. STEP
1	2.90E+07	21.40	729.00	45.00	1.30	0.00	14	1

V.A.3.--SOIL PROPERTIES

<-----START PILE NO.	CONSTANT COEFFICIENT (PSI)	LINEAR COEFFICIENT (PCI) ----->	STOP PILE NO.	PILE NO. STEP
1	0.000	10.000	14	1

a. (Continued)

Figure 48. (Sheet 2 of 6)

V.A.4.--PILE HEAD STIFFNESS MATRICES
NONE

V.A.4.--PILE BATTER DATA

<----START---->		STOP	PILE
PILE NO.	BATTER (FT/FT)	PILE NO.	NO. STEP
11	3.00	14	1

V.A.5.--PILE LOAD COMPARISON DATA

V.A.5.A.--ALLOWABLE LOADS

START PILE NO.	<------ALLOWABLE AXIAL LOAD------->				ALLOW. MOMENT (K-FT)	STOP PILE NO.	PILE NO. STEP
	<-AXIAL ONLY->		<AXIAL WITH MOM.>				
	COMPR. (K)	TENS. (K)	COMPR. (K)	TENS. (K)			
1	215.	88.	364.	364.	196.	14	1

V.A.5.B.--MOMENT/STRESS FACTORS

START PILE NO.	MOMENT MAG. FACT.	MAX. MOM. FACTOR (IN)	<OVERSTRESS FACTOR>		STOP PILE NO.	PILE NO. STEP
			COMPR.	TENS.		
1	1.000	56.600	1.330	1.330	14	1

V.B.-- LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 60.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA
RIGHTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)
LEFTSIDE UPLIFT WATER ELEVATION = 62.00 (FT)

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 55.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 45.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 45.00 (FT)

a. (Continued)

Figure 48. (Sheet 3 of 6)

VII.--ADDITIONAL LOAD DATA

VII.A.1.--ADDITIONAL LOADS ON RIGHTSIDE EXTERNAL STEM FACE

CONCENTRATED LOAD DATA

ELEVATION AT LOAD (FT)	HORIZONTAL LOAD (PLF)	VERTICAL LOAD (PLF)
70.00	1000.00	0.00

DISTRIBUTED LOAD DATA
NONE

VII.A.2.--ADDITIONAL LOADS ON LEFTSIDE EXTERNAL STEM FACE
NONE

VII.B.1.--ADDITIONAL LOADS ON RIGHTSIDE INTERIOR STEM FACE
NONE

VII.B.2.--ADDITIONAL LOADS ON LEFTSIDE INTERIOR STEM FACE
NONE

VII.C.1--ADDITIONAL LOADS ON RIGHTSIDE STEM TOP
NONE

VII.C.2--ADDITIONAL LOADS ON LEFTSIDE STEM TOP
NONE

VII.D.1.--ADDITIONAL LOADS ON RIGHTSIDE OF CHAMBER FLOOR
NONE

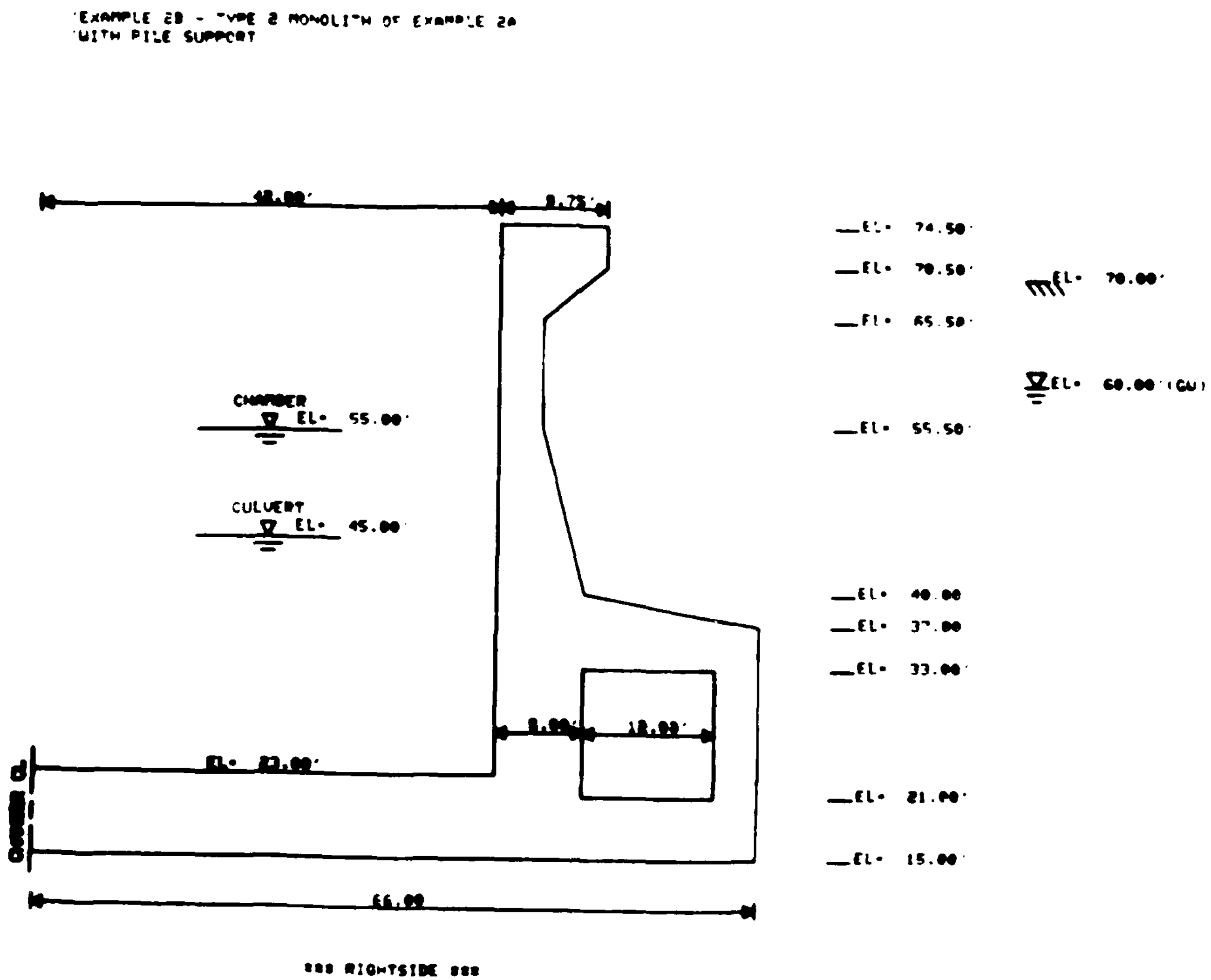
VII.D.2.--ADDITIONAL LOADS ON LEFTSIDE OF CHAMBER FLOOR
NONE

VII.E.1.--ADDITIONAL LOADS ON RIGHTSIDE OF STRUCTURE BASE
NONE

VII.E.2.--ADDITIONAL LOADS ON LEFTSIDE OF STRUCTURE BASE
NONE

a. (Concluded)

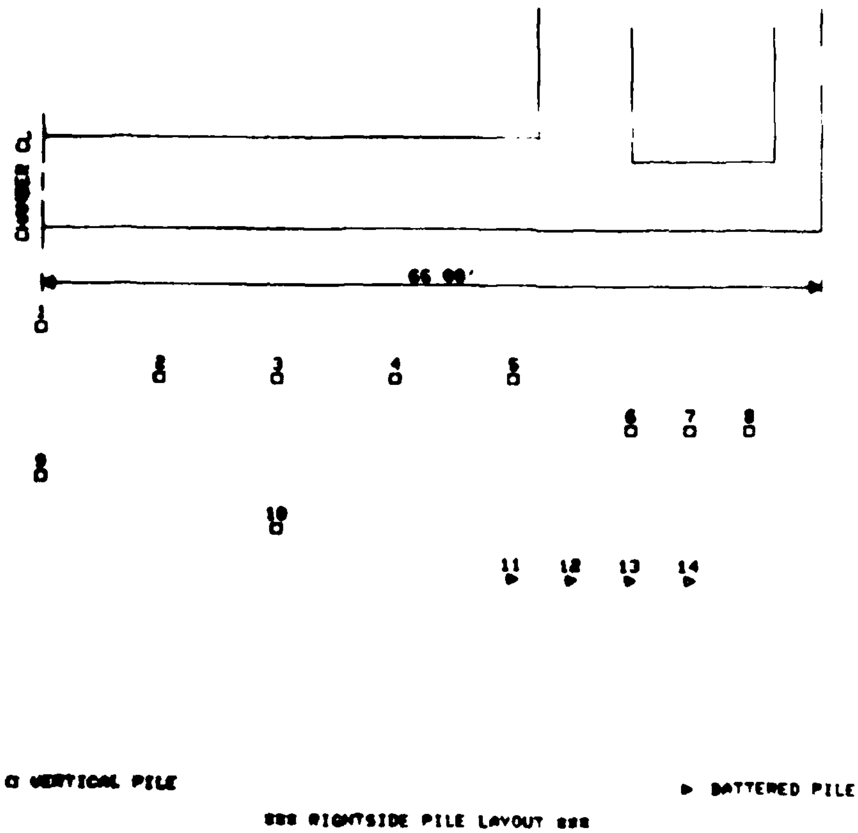
Figure 48. (Sheet 4 of 6)



b. Plots of rightside geometry (Continued)

Figure 48. (Sheet 5 of 6)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT



b. (Concluded)

Figure 48. (Sheet 6 of 6)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 15:37:32

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

```
**************************************
*  RESULTS OF EQUILIBRIUM ANALYSIS  *
**************************************
```

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
70.000	0.	0.	0.	0.
65.500	5.4900E+02	3.2940E+02	0.	0.
60.000	1.2200E+03	7.3200E+02	0.	0.
55.500	1.4878E+03	8.9265E+02	0.	2.8125E+02
55.000	1.5175E+03	9.1050E+02	0.	3.1250E+02
40.000	2.4100E+03	1.4460E+03	0.	1.2500E+03
37.000	2.5885E+03	1.5531E+03	0.	1.4375E+03
33.000	2.8265E+03	1.6959E+03	0.	1.6875E+03
23.000	3.4215E+03	2.0529E+03	0.	2.3125E+03
21.000	3.5405E+03	2.1243E+03	0.	2.4375E+03
15.000	3.8975E+03	2.3385E+03	0.	2.8125E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	2.9375E+03
10.000	0.	2.9375E+03
20.000	0.	2.9375E+03
30.000	0.	2.9375E+03
40.000	0.	2.9375E+03
42.000	0.	2.9375E+03
45.000	0.	2.9375E+03
50.000	0.	2.9375E+03
55.000	0.	2.9375E+03
60.000	0.	2.9375E+03
62.000	0.	2.9375E+03
66.000	0.	2.9375E+03

Figure 49. Results of equilibrium analysis for Example 2B (Sheet 1 of 3)

II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	4.3648E+05	2.7818E+05	-1.0515E+07
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
ADDL EXT STEM LOADS	6.0000E+03	0.	2.8200E+05
CONCRETE		8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	6.3017E+05	6.9724E+05	-2.8599E+07

III.--EFFECTS ON STRUCTURE LEFTSIDE

III.A.--PRESSURES ON LEFTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
74.500	0.	0.	0.	0.
70.500	0.	0.	0.	0.
65.500	0.	0.	0.	0.
60.000	0.	0.	0.	0.
55.500	2.6775E+02	1.6065E+02	0.	2.8125E+02
55.000	2.9750E+02	1.7850E+02	0.	3.1250E+02
40.000	1.1900E+03	7.1400E+02	0.	1.2500E+03
37.000	1.3685E+03	8.2110E+02	0.	1.4375E+03
33.000	1.6065E+03	9.6390E+02	0.	1.6875E+03
23.000	2.2015E+03	1.3209E+03	0.	2.3125E+03
21.000	2.3205E+03	1.3923E+03	0.	2.4375E+03
15.000	2.6775E+03	1.6065E+03	0.	2.8125E+03

III.B.--PRESSURE ON LEFTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	2.9375E+03
10.000	0.	2.9375E+03
20.000	0.	2.9375E+03
30.000	0.	2.9375E+03
40.000	0.	2.9375E+03
42.000	0.	2.9375E+03
45.000	0.	2.9375E+03
50.000	0.	2.9375E+03
55.000	0.	2.9375E+03
60.000	0.	2.9375E+03
62.000	0.	2.9375E+03
66.000	0.	2.9375E+03

Figure 49. (Sheet 2 of 3)

III.C.--RESULTANTS OF LOADS ON STRUCTURE LEFTSIDE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE MOMENT IS CLOCKWISE ABOUT CHAMBER
FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)

ITEM	HORIZONTAL	VERTICAL	MOMENT
BACKFILL	2.1688E+05	1.4030E+05	-6.4746E+06
GROUND/SURCH WATER	3.7969E+05	1.4738E+05	-5.7379E+06
INTERNAL WATER	-1.9200E+05	5.5800E+05	-1.5656E+07
UPLIFT WATER	0.	-1.1633E+06	3.8387E+07
CONCRETE		8.7694E+05	-3.5359E+07
TOTAL THIS SIDE	4.0457E+05	5.5936E+05	-2.4841E+07

IV.--NET RESULTANTS OF ALL LOADS
(POSITIVE HORIZONTAL IS TO THE RIGHT)
(POSITIVE VERTICAL IS DOWN)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
(UNITS ARE POUNDS AND FEET)
TOTAL HORIZONTAL = -2.2560E+05
TOTAL VERTICAL = 1.2566E+06
TOTAL MOMENT = -3.7581E+06

Figure 49. (Sheet 3 of 3)

of these comparisons on the behavior of the system.

144. The results of an analysis of this structure obtained with GTSTRUDL are given in Appendix B.

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 15:37:33

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

```
**********************
*  FRAME MODEL DATA  *
**********************
```

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

		<--------------CORNER LOCATIONS-------------->						
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	62.00	62.00	66.00	66.00	66.00	62.00	64.00
	ELEVATION	15.00	21.00	21.00	21.00	15.00	15.00	18.00
2	X-COORD.	42.00	42.00	50.00	50.00	50.00	42.00	46.00
	ELEVATION	15.00	23.00	23.00	21.00	15.00	15.00	19.00
3	X-COORD.	42.00	42.00	50.00	50.00	50.00	50.00	46.00
	ELEVATION	33.00	40.00	40.00	40.00	33.00	33.00	36.50
4	X-COORD.	62.00	62.00	66.00	66.00	66.00	66.00	63.94
	ELEVATION	33.00	37.75	37.00	33.00	33.00	33.00	35.19
6	X-COORD.	42.00	42.00	51.75	51.75	46.00	46.00	46.30
	ELEVATION	65.50	74.50	74.50	70.50	65.50	65.50	70.56

II.B.--JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	19.00000
2	10.00000	19.00000
3	20.00000	19.00000
4	30.00000	19.00000
5	40.00000	19.00000
6	46.00000	19.00000
7	55.00000	18.00000
8	60.00000	18.00000
9	64.00000	18.00000
10	63.94286	35.19286
11	46.00000	36.50000
12	44.00000	55.50000
13	46.29543	70.55508

a. Data analysis (Continued)

Figure 50. Frame model data for Example 2B (Sheet 1 of 5)

III.B.--JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	19.00000
2	10.00000	19.00000
3	20.00000	19.00000
4	30.00000	19.00000
5	40.00000	19.00000
6	46.00000	19.00000
7	55.00000	18.00000
8	60.00000	18.00000
9	64.00000	18.00000
10	63.94286	35.19286
11	46.00000	36.50000
12	44.00000	55.50000
13	46.29543	70.55508

III.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	19.00	10.00	19.00	8.00	8.00
2	2	3	10.00	19.00	20.00	19.00	8.00	8.00
3	3	4	20.00	19.00	30.00	19.00	8.00	8.00
4	4	5	30.00	19.00	40.00	19.00	8.00	8.00
5	5	6	40.00	19.00	42.00	19.00	8.00	8.00
6	6	7	50.00	18.00	55.00	18.00	6.00	6.00
7	7	8	55.00	18.00	60.00	18.00	6.00	6.00
8	8	9	60.00	18.00	62.00	18.00	6.00	6.00
9	9	10	64.00	21.00	64.00	33.00	4.00	4.00
10	6	11	46.00	23.00	46.00	33.00	8.00	8.00
11	11	10	50.00	36.50	62.00	35.38	7.00	4.75
12	11	12	46.00	40.00	44.00	55.50	8.00	4.00
13	12	13	44.00	55.50	44.00	65.50	4.00	4.00

III.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE	X-COORD.	BATTER	<------------STIFFNESS COEFFICIENTS------------			
NO.	(FT)	(FT/FT)	B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
2	10.00	0.00	2.6532E+05	1.7928E+07	0.	0.
3	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
4	30.00	0.00	2.6532E+05	1.7928E+07	0.	0.
5	40.00	0.00	2.6532E+05	1.7928E+07	0.	0.
6	50.00	0.00	2.6532E+05	1.7928E+07	0.	0.
7	55.00	0.00	2.6532E+05	1.7928E+07	0.	0.
8	60.00	0.00	2.6532E+05	1.7928E+07	0.	0.
9	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
10	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
11	40.00	3.00	2.6532E+05	1.7928E+07	0.	0.
12	45.00	3.00	2.6532E+05	1.7928E+07	0.	0.
13	50.00	3.00	2.6532E+05	1.7928E+07	0.	0.
14	55.00	3.00	2.6532E+05	1.7928E+07	0.	0.

a. (Continued)

Figure 50. (Sheet 2 of 5)

II.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

MEM NO	FROM JT	TO JT	<COORDS AT ENDS OF FLEX LENGTH> <--FROM END--> X	ELEV	<---TO END---> X	ELEV	<-MEMBER DEPTH--> FROM END	TO END
1	1	2	0.00	19.00	10.00	19.00	8.00	8.00
2	2	3	10.00	19.00	20.00	19.00	8.00	8.00
3	3	4	20.00	19.00	30.00	19.00	8.00	8.00
4	4	5	30.00	19.00	40.00	19.00	8.00	8.00
5	5	6	40.00	19.00	42.00	19.00	8.00	8.00
6	6	7	50.00	18.00	55.00	18.00	6.00	6.00
7	7	8	55.00	18.00	60.00	18.00	6.00	6.00
8	8	9	60.00	18.00	62.00	18.00	6.00	6.00
9	9	10	64.00	21.00	64.00	33.00	4.00	4.00
10	6	11	46.00	23.00	46.00	33.00	8.00	8.00
11	11	10	50.00	36.50	62.00	35.38	7.00	4.75
12	11	12	46.00	40.00	44.00	55.50	8.00	4.00
13	12	13	44.00	55.50	44.00	65.50	4.00	4.00

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE NO.	X-COORD. (FT)	BATTER (FT/FT)	<-------------STIFFNESS COEFFICIENTS------------ B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
2	10.00	0.00	2.6532E+05	1.7928E+07	0.	0.
3	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
4	30.00	0.00	2.6532E+05	1.7928E+07	0.	0.
5	40.00	0.00	2.6532E+05	1.7928E+07	0.	0.
6	50.00	0.00	2.6532E+05	1.7928E+07	0.	0.
7	55.00	0.00	2.6532E+05	1.7928E+07	0.	0.
8	60.00	0.00	2.6532E+05	1.7928E+07	0.	0.
9	0.00	0.00	2.6532E+05	1.7928E+07	0.	0.
10	20.00	0.00	2.6532E+05	1.7928E+07	0.	0.
11	40.00	3.00	2.6532E+05	1.7928E+07	0.	0.
12	45.00	3.00	2.6532E+05	1.7928E+07	0.	0.
13	50.00	3.00	2.6532E+05	1.7928E+07	0.	0.
14	55.00	3.00	2.6532E+05	1.7928E+07	0.	0.

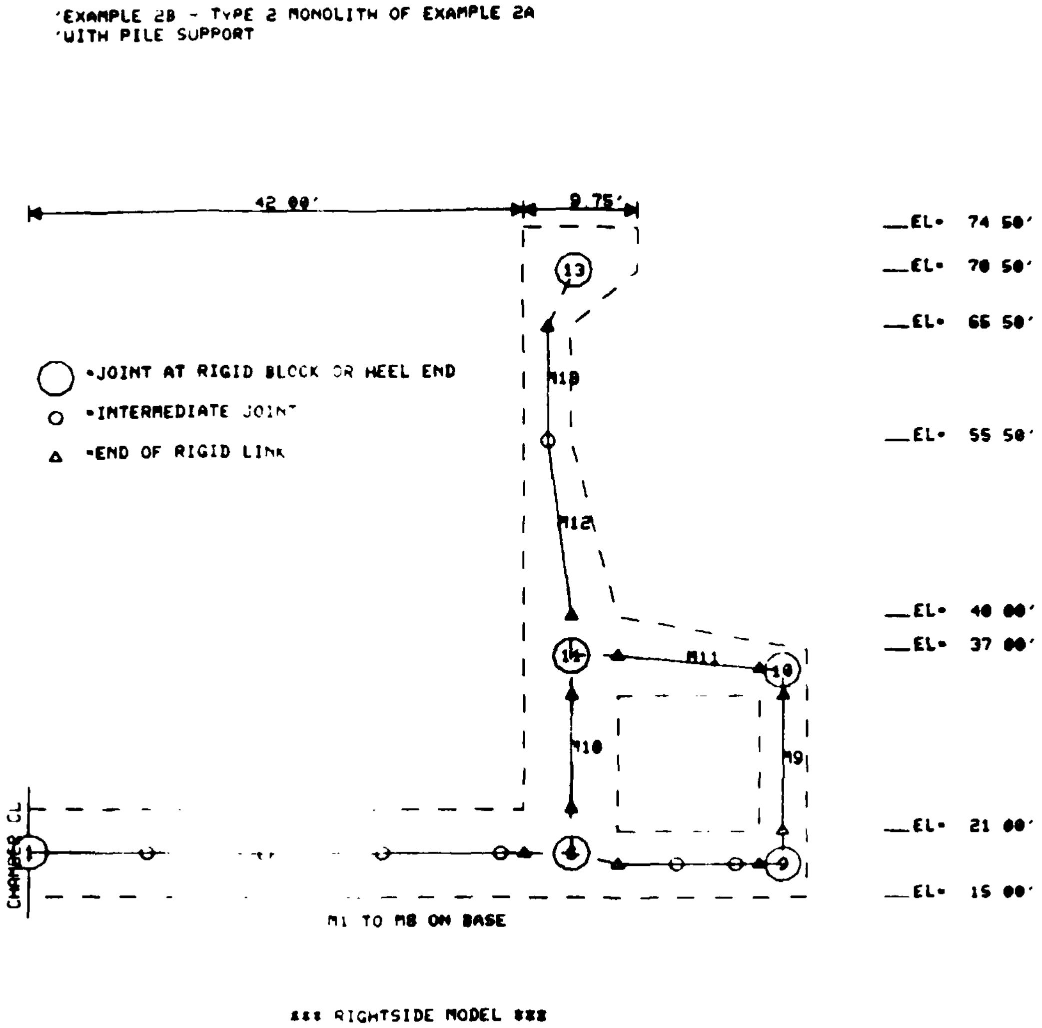
III.-- LEFTSIDE FRAME MODEL DATA

III.A.--RIGID BLOCK DATA (FT) - TYPE 2 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

BLOCK	CORNER NO.	<--------------CORNER LOCATIONS--------------> 1	2	3	4	5	6	CENTROID
1	X-COORD.	62.00	62.00	66.00	66.00	66.00	62.00	64.00
	ELEVATION	15.00	21.00	21.00	21.00	15.00	15.00	18.00
2	X-COORD.	42.00	42.00	50.00	50.00	50.00	42.00	46.00
	ELEVATION	15.00	23.00	23.00	21.00	15.00	15.00	19.00
3	X-COORD.	42.00	42.00	50.00	50.00	50.00	50.00	46.00
	ELEVATION	33.00	40.00	40.00	40.00	33.00	33.00	36.50
4	X-COORD.	62.00	62.00	66.00	66.00	66.00	66.00	63.94
	ELEVATION	33.00	37.75	37.00	33.00	33.00	33.00	35.19
6	X-COORD.	42.00	42.00	51.75	51.75	46.00	46.00	46.30
	ELEVATION	65.50	74.50	74.50	70.50	65.50	65.50	70.56

a. (Concluded)

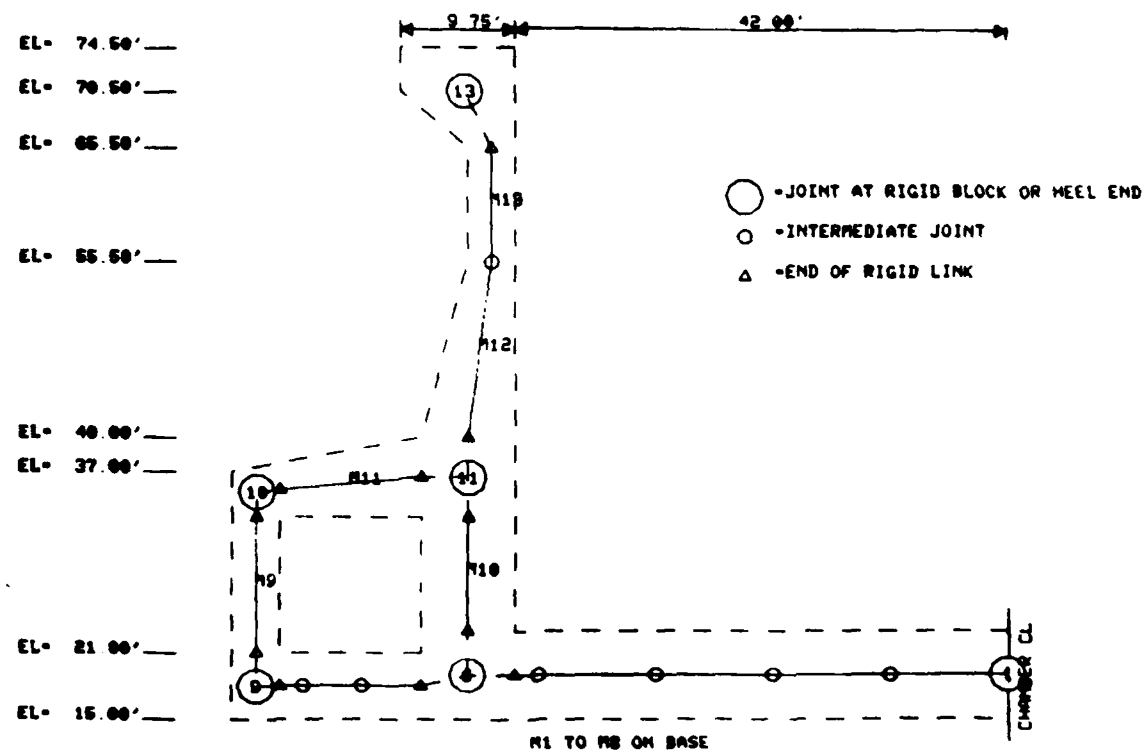
Figure 50. (Sheet 3 of 5)



b. Plots of rightside geometry

Figure 50. (Sheet 4 of 5)

'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT



*** LEFTSIDE MODEL ***

c. Plots of leftside geometry

Figure 50. (Sheet 5 of 5)

PROGRAM CUFRAM - ANALYSIS OF TWO DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 15:37:35

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

****
* RESULTS OF FRAME ANALYSIS *
****

II.--STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	19.00	1.551E-02	1.309E-03	-7.127E-05
2	10.00	19.00	1.580E-02	2.369E-03	-1.369E-04
3	20.00	19.00	1.608E-02	4.050E-03	-1.840E-04
4	30.00	19.00	1.637E-02	6.042E-03	-1.436E-04
5	40.00	19.00	1.666E-02	6.880E-03	8.632E-05
6	46.00	19.00	1.672E-02	6.094E-03	1.625E-04
7	55.00	18.00	1.666E-02	4.372E-03	2.329E-04
8	60.00	18.00	1.676E-02	3.094E-03	2.818E-04
9	64.00	18.00	1.680E-02	1.926E-03	3.051E-04
		***** STEM JOINTS *****			
10	63.94	35.19	2.172E-02	2.059E-03	1.920E-04
11	46.00	36.50	2.191E-02	6.402E-03	3.606E-04
12	44.00	55.50	3.147E-02	7.552E-03	6.421E-04
13	46.30	70.56	4.150E-02	6.121E-03	6.548E-04

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 2 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS CLOCKWISE.)

JT NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	19.00	-1.551E-02	1.309E-03	7.127E-05
2	10.00	19.00	-1.523E-02	9.272E-04	1.476E-05
3	20.00	19.00	-1.496E-02	1.002E-03	-1.970E-05
4	30.00	19.00	-1.469E-02	1.299E-03	-2.121E-05
5	40.00	19.00	-1.441E-02	1.408E-03	2.131E-05
6	46.00	19.00	-1.436E-02	1.233E-03	4.014E-05
7	55.00	18.00	-1.431E-02	8.289E-04	3.330E-05
8	60.00	18.00	-1.422E-02	7.172E-04	4.296E-05
9	64.00	18.00	-1.419E-02	5.332E-04	5.890E-05

Figure 51. Results of frame analysis for Example 2B (Sheet 1 of 6)

		***** STEM JOINTS *****			
10	63.94	35.19	-1.290E-02	6.780E-04	3.573E-05
11	46.00	36.50	-1.293E-02	1.466E-03	9.001E-05
12	44.00	55.50	-1.070E-02	1.794E-03	9.824E-05
13	46.30	70.56	-1.031E-02	1.899E-03	-1.068E-05

III.--FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 2 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

MEM NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	19.00	5.861E+05	1.675E+04	-7.833E+05
	10.00	19.00	5.861E+05	-9.986E+02	-6.946E+05
2	10.00	19.00	5.905E+05	4.348E+04	-7.119E+05
	20.00	19.00	5.905E+05	-2.773E+04	-3.559E+05
3	20.00	19.00	5.994E+05	1.730E+05	-3.916E+05
	30.00	19.00	5.994E+05	-1.572E+05	1.259E+06
4	30.00	19.00	6.039E+05	2.655E+05	1.241E+06
	40.00	19.00	6.039E+05	-2.498E+05	3.818E+06
5	40.00	19.00	6.049E+05	3.979E+05	3.814E+06
	42.00	19.00	6.049E+05	-3.947E+05	4.606E+06
6	50.00	18.00	3.062E+05	-8.067E+04	8.459E+05
	55.00	18.00	3.062E+05	6.454E+04	4.828E+05
7	55.00	18.00	3.197E+05	-5.082E+01	4.424E+05
	60.00	18.00	3.197E+05	-1.607E+04	4.824E+05
8	60.00	18.00	3.239E+05	7.155E+04	4.698E+05
	62.00	18.00	3.239E+05	-7.800E+04	6.193E+05
		***** CULVERT MEMBERS *****			
9	64.00	21.00	1.269E+05	-1.491E+05	3.387E+05
	64.00	33.00	8.370E+04	-5.595E+04	-1.891E+05
10	46.00	23.00	6.752E+05	-2.890E+05	3.699E+06
	46.00	33.00	6.032E+05	3.265E+05	6.215E+05
11	50.00	36.50	1.538E+05	3.262E+05	-2.102E+06
	62.00	35.38	1.425E+05	-4.106E+04	-3.994E+03
		***** STEM MEMBERS *****			
12	46.00	40.00	2.159E+05	-2.209E+05	2.142E+06
	44.00	55.50	8.587E+04	6.522E+04	1.926E+05
13	44.00	55.50	9.351E+04	-5.369E+04	1.926E+05
	44.00	65.50	5.751E+04	1.045E+04	-8.617E+04

Figure 51. (Sheet 2 of 6)

III.B.-- LEFTSIDE MEMBERS - TYPE 2 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

MEM NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	19.00	5.777E+05	3.021E+04	-7.498E+05
	10.00	19.00	5.777E+05	-1.446E+04	-5.265E+05
2	10.00	19.00	5.737E+05	3.108E+04	-5.103E+05
	20.00	19.00	5.737E+05	-1.533E+04	-2.782E+05
3	20.00	19.00	5.658E+05	5.124E+04	-2.466E+05
	30.00	19.00	5.658E+05	-3.549E+04	1.870E+05
4	30.00	19.00	5.619E+05	5.878E+04	2.025E+05
	40.00	19.00	5.619E+05	-4.303E+04	7.116E+05
5	40.00	19.00	5.212E+05	1.679E+05	8.747E+05
	42.00	19.00	5.212E+05	-1.647E+05	1.207E+06
6	50.00	18.00	3.026E+05	-6.010E+04	7.295E+04
	55.00	18.00	3.026E+05	4.398E+04	-1.873E+05
7	55.00	18.00	2.651E+05	6.062E+04	-7.480E+04
	60.00	18.00	2.651E+05	-7.674E+04	2.686E+05
8	60.00	18.00	2.613E+05	8.960E+04	2.800E+05
	62.00	18.00	2.613E+05	-9.605E+04	4.657E+05
		***** CULVERT MEMBERS *****			
9	64.00	21.00	1.450E+05	-1.128E+05	3.300E+05
	64.00	33.00	1.018E+05	-3.953E+04	-7.874E+04
10	46.00	23.00	5.193E+05	-1.260E+05	1.244E+06
	46.00	33.00	4.473E+05	1.635E+05	-2.037E+05
11	50.00	36.50	1.195E+05	1.872E+05	-9.653E+05
	62.00	35.38	1.098E+05	9.546E+03	1.928E+04
		***** STEM MEMBERS *****			
12	46.00	40.00	2.101E+05	-1.034E+05	6.147E+05
	44.00	55.50	1.004E+05	1.897E+04	-1.426E+05
13	44.00	55.50	1.020E+05	-5.966E+03	-1.426E+05
	44.00	65.50	6.604E+04	0.	-1.516E+05

Figure 51. (Sheet 3 of 6)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 15:37:35

I.--HEADING
'EXAMPLE 2B - TYPE 2 MONOLITH OF EXAMPLE 2A
'WITH PILE SUPPORT

II.--RESULTS FOR RIGHTSIDE PILES

II.A.--PILE HEAD FORCES AND DISPLACEMENTS
(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CHAMBER CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CHAMBER CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS---->		
NO.	CHAMB CL	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	2.348E+04	-4.192E+03	0.	1.309E-03	-1.580E-02	-7.127E-05
2	10.00	4.248E+04	-4.336E+03	0.	2.369E-03	-1.634E-02	-1.369E-04
3	20.00	7.261E+04	-4.462E+03	0.	4.050E-03	-1.682E-02	-1.840E-04
4	30.00	1.083E+05	-4.496E+03	0.	6.042E-03	-1.694E-02	-1.436E-04
5	40.00	1.233E+05	-4.329E+03	0.	6.880E-03	-1.632E-02	8.632E-05
6	50.00	9.760E+04	-4.264E+03	0.	5.444E-03	-1.607E-02	1.625E-04
7	55.00	7.838E+04	-4.234E+03	0.	4.372E-03	-1.596E-02	2.329E-04
8	60.00	5.548E+04	-4.222E+03	0.	3.094E-03	-1.591E-02	2.818E-04
9	0.00	2.348E+04	-4.192E+03	0.	1.309E-03	-1.580E-02	-7.127E-05
10	20.00	7.261E+04	-4.462E+03	0.	4.050E-03	-1.682E-02	-1.840E-04
11	40.00	2.452E+04	-4.684E+03	0.	1.368E-03	-1.765E-02	8.632E-05
12	45.00	1.531E+04	-4.570E+03	0.	8.537E-04	-1.722E-02	1.625E-04
13	50.00	1.489E+03	-4.501E+03	0.	8.306E-05	-1.697E-02	1.625E-04
14	55.00	-1.610E+04	-4.383E+03	0.	-8.982E-04	-1.652E-02	2.329E-04

II.B.--PILE ALLOWABLES COMPARISONS

PILE	DIST. TO	MAXIMUM	<ALLOWABLES COMPARISON RATIOS>	
NO.	CHAMB CL	MOMENT	AXIAL FORCE	AXIAL FORCE
	(FT)	(LB-FT)	ONLY	AND MOMENT
1	0.00	1.98E+04	.082	.124
2	10.00	2.05E+04	.149	.166
3	20.00	2.10E+04	.254	.231
4	30.00	2.12E+04	.379	.305
5	40.00	2.04E+04	.431	.333
6	50.00	2.01E+04	.341	.279
7	55.00	2.00E+04	.274	.239
8	60.00	1.99E+04	.194	.191
9	0.00	1.98E+04	.082	.124
10	20.00	2.10E+04	.254	.231
11	40.00	2.21E+04	.086	.135
12	45.00	2.16E+04	.054	.114
13	50.00	2.12E+04	.005	.085
14	55.00	2.07E+04	.138	.113

Figure 51. (Sheet 4 of 6)

III.--RESULTS FOR LEFTSIDE PILES

III.A.--PILE HEAD FORCES AND DISPLACEMENTS
(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CHAMBER CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CHAMBER CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS---->		
NO.	CHAMB CL	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	2.348E+04	4.192E+03	0.	1.309E-03	1.580E-02	7.127E-05
2	10.00	1.662E+04	4.058E+03	0.	9.272E-04	1.529E-02	1.476E-05
3	20.00	1.796E+04	3.948E+03	0.	1.002E-03	1.488E-02	-1.970E-05
4	30.00	2.329E+04	3.874E+03	0.	1.299E-03	1.460E-02	-2.121E-05
5	40.00	2.524E+04	3.847E+03	0.	1.408E-03	1.450E-02	2.131E-05
6	50.00	1.922E+04	3.854E+03	0.	1.072E-03	1.452E-02	4.014E-05
7	55.00	1.486E+04	3.822E+03	0.	8.289E-04	1.441E-02	3.330E-05
8	60.00	1.286E+04	3.807E+03	0.	7.172E-04	1.435E-02	4.296E-05
9	0.00	2.348E+04	4.192E+03	0.	1.309E-03	1.580E-02	7.127E-05
10	20.00	1.796E+04	3.948E+03	0.	1.002E-03	1.488E-02	-1.970E-05
11	40.00	1.061E+05	3.531E+03	0.	5.921E-03	1.331E-02	2.131E-05
12	45.00	1.040E+05	3.549E+03	0.	5.801E-03	1.338E-02	4.014E-05
13	50.00	1.006E+05	3.566E+03	0.	5.610E-03	1.344E-02	4.014E-05
14	55.00	9.578E+04	3.557E+03	0.	5.342E-03	1.341E-02	3.330E-05

Figure 51. (Sheet 5 of 6)

III.B.--PILE ALLOWABLES COMPARISONS

PILE NO.	DIST. TO CHAMB CL (FT)	MAXIMUM MOMENT (LB-FT)	<ALLOWABLES COMPARISON RATIOS> AXIAL FORCE ONLY	AXIAL FORCE AND MOMENT
1	0.00	-1.98E+04	.082	.124
2	10.00	-1.91E+04	.058	.108
3	20.00	-1.86E+04	.063	.109
4	30.00	-1.83E+04	.081	.118
5	40.00	-1.81E+04	.088	.122
6	50.00	-1.82E+04	.067	.109
7	55.00	-1.80E+04	.052	.100
8	60.00	-1.80E+04	.045	.095
9	0.00	-1.98E+04	.082	.124
10	20.00	-1.86E+04	.063	.109
11	40.00	-1.67E+04	.371	.283
12	45.00	-1.67E+04	.364	.279
13	50.00	-1.68E+04	.352	.272
14	55.00	-1.68E+04	.335	.262

IV.--RESULTANTS OF PILE FORCES ON STRUCTURE

(POSITIVE HORIZONTAL IF TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE
(UNITS ARE POUNDS AND FEET)

	HORIZONTAL	VERTICAL	MOMENT
RIGHTSIDE PILES	4.8230E+04	7.0397E+05	2.5505E+07
LEFTSIDE PILES	1.7737E+05	5.5263E+05	-2.1746E+07
TOTAL	2.2560E+05	1.2566E+06	3.7581E+06

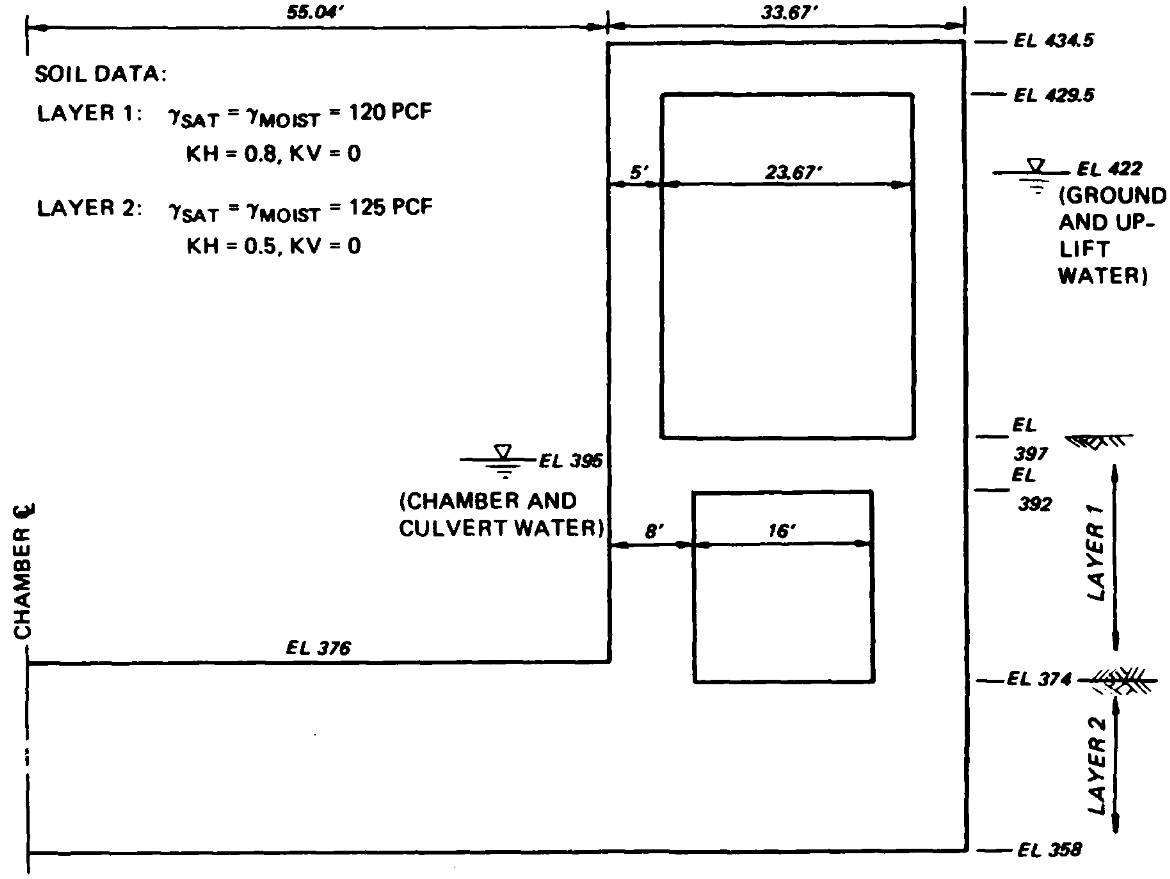
NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CHAMBER CENTERLINE.

Figure 51. (Sheet 6 of 6)

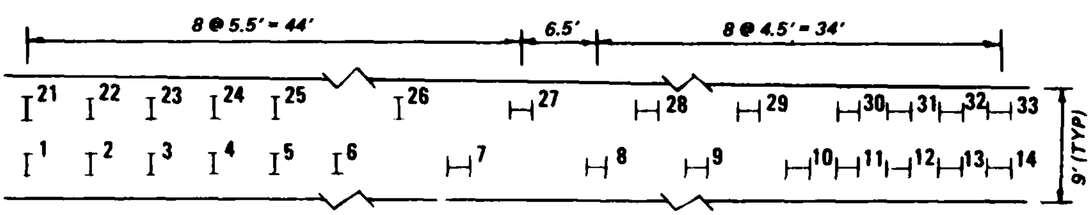
Example 3--Type 31 Monolith

145. The symmetric system and pile layout are shown in Figure 52. The predefined input file for this system is shown in Figure 53. Note that the number identifiers assigned to the piles need not be in sequential order. Also note that the pile/soil data initially assigned stiffness matrices representative of bending about the weak axis. The data provided subsequently for bending about the strong axis override the initial assignment. Only those piles for which layout data are provided are considered in the analysis. For illustration, uplift water effects are provided by an input distribution.

146. An echoprint of input data is given in Figure 54, with equilibrium results shown in Figure 55. Frame model data are given in Figure 56, and results of the frame analysis are shown in Figure 57.



a. Structure, soil, and water data



b. Pile layout

Figure 52. System for Example 3

***** INPUT FILE FOR EXAMPLE 3 *****

```
1000 'EXAMPLE 3 - TYPE 31 MONOLITH
1010 METHOD FRAME 1
1020 STRUCTURE 3.E6 .2 150 9
1030 FLOOR 55.04 376 0
1040 BASE BOTH 88.71 358
1050 STEM BOTH 7 33.67 434.5 33.67 431.75 33.67 429.5
1060 33.67 397 33.67 392 33.67 374 33.67 374
1070 CULVERT BOTH 8 16 374 18 0
1080 VOID BOTH 5 23.67 397 32.5 0
1090 REACTION PILES
1100 PILES BOTH
1110 LAYOUT 1 0 6 1 5.5
1120 LAYOUT 7 38.5 8 1 12
1130 LAYOUT 9 59.5
1140 LAYOUT 10 68.5 14 1 4.5
1150 LAYOUT 21 0 25 1 5.5
1160 LAYOUT 26 33 27 1 11
1170 LAYOUT 28 55 29 1 9
1180 LAYOUT 30 73 33 1 4.5
1190 (STIFFNESS MATRICES FOR BENDING ABOUT WEAK AXIS)
1200 STIFFNESS 1 5.49E5 2.00E7 2.32E7 2.77E6 50 1
1210 (STIFFNESS MATRICES FOR BENDING ABOUT STRONG AXIS)
1220 STIFFNESS 7 8.23E5 2.00E7 5.23E7 5.09E6 14 1
1230 STIFFNESS 27 8.23E5 2.00E7 5.23E7 5.09E6 33 1
1240 BACKFILL BOTH SOIL 2 0
1250 397 120 120 .8 .8 0 0
1260 374 125 125 .5 .5 0 0
1270 WATER 62.5
1280 EXTERNAL BOTH ELEVATION 422
1290 UPLIFT PRESSURE
1300 BOTH 2 0 4000 100 4000
1310 INTERNAL 395 395 395
1320 FINISH
```

Figure 53. Input file for Example 3

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85                                        TIME: 16:43:38

I.--HEADING
  'EXAMPLE 3 - TYPE 31 MONOLITH

                 ****************
                 *  INPUT DATA  *
                 ****************

II.--PLANE FRAME ANALYSIS
     RIGID LINK FACTOR =        1.00

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =    3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =      .20
     UNIT WEIGHT OF CONCRETE            =  150.0     (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    9.00    (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH       =      55.04 (FT)
     FLOOR ELEVATION   =     376.00 (FT)
     FLOOR FILLET SIZE =       0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CHAMBER CL       ELEVATION
          (FT)            (FT)
         88.71          358.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE       ELEVATION
          (FT)            (FT)
         33.67          434.50
         33.67          431.75
         33.67          429.50
         33.67          397.00
         33.67          392.00
         33.67          374.00
         33.67          374.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

Figure 54. Echoprint of input data for Example 3 (Sheet 1 of 3)

III.E.--CULVERT DATA

III.E.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	8.00 (FT)
CULVERT WIDTH	=	16.00 (FT)
ELEVATION AT CULVERT FLOOR	=	374.00 (FT)
CULVERT HEIGHT	=	18.00 (FT)
CULVERT FILLET SIZE	=	0.00 (FT)

III.E.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA

III.F.1.--RIGHTSIDE

DISTANCE FROM STEM FACE TO INTERIOR SIDE	=	5.00 (FT)
VOID WIDTH	=	23.67 (FT)
ELEVATION AT VOID BOTTOM	=	397.00 (FT)
VOID HEIGHT	=	32.50 (FT)
VOID TIES		NONE

III.F.2.--LEFTSIDE
SYMMETRIC WITH RIGHTSIDE

IV.--BACKFILL DATA

IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE = 0.00 (PSF))

ELEV AT TOP (FT)	SATURATED UNIT WT. (PCF)	MOIST UNIT WT. (PCF)	<-PRESSURE COEFFICIENTS-> HORIZONTAL TOP	BOT.	SHEAR TOP	BOT.
397.00	120.0	120.0	.800	.800	0.000	0.000
374.00	125.0	125.0	.500	.500	0.000	0.000

IV.B.--LEFTSIDE SOIL LAYER DATA
SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA

V.A.--RIGHTSIDE PILE DATA

V.A.1.--PILE LAYOUT DATA

<------START-----> PILE NO.	DIST. FROM CHAMBER CL (FT)	STOP PILE NO.	PILE NO. STEP	STEP IN CL DIST. (FT)
1	0.00	6	1	5.50
7	38.50	8	1	12.00
9	59.50	9	1	0.00
10	68.50	14	1	4.50
21	0.00	25	1	5.50
26	33.00	27	1	11.00
28	55.00	29	1	9.00
30	73.00	33	1	4.50

Figure 54. (Sheet 2 of 3)

V.A.2.--PILE PROPERTIES
NONE

V.A.2.--SOIL PROPERTIES
NONE

V.A.4.--PILE HEAD STIFFNESS MATRICES

<-------START					------->	STOP	PILE
PILE	<----STIFFNESS COEFFICIENTS			---->	PILE	NO.
NO.	B11 (LB/IN)	B22 (LB/IN)	B33 (LB-IN)	B13 (LB)	NO.	STEP
1	5.490E+05	2.000E+07	2.320E+07	2.770E+06	50	1
7	8.230E+05	2.000E+07	5.230E+07	5.090E+06	14	1
27	8.230E+05	2.000E+07	5.230E+07	5.090E+06	33	1

V.A.4.--PILE BATTER DATA
NONE

V.A.5.--PILE LOAD COMPARISON DATA
NONE

V.B.-- LEFTSIDE PILE DATA
SYMMETRIC WITH RIGHTSIDE

VI.--WATER DATA
WATER UNIT WEIGHT = 62.5 (PCF)

VI.A.--EXTERNAL WATER DATA

VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
GROUND WATER ELEVATION = 422.00 (FT)
SURCHARGE WATER NONE

VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
SYMMETRIC WITH RIGHTSIDE

VI.B.--UPLIFT WATER DATA

VI.B.1.--RIGHTSIDE UPLIFT WATER PRESSURE DISTRIBUTION

DIST. FROM CHAMBER CL (FT)	UPLIFT PRESSURE (PSF)
0.00	4000.00
100.00	4000.00

VI.B.2.-- LEFTSIDE UPLIFT WATER PRESSURE DISTRIBUTION
SYMMETRIC WITH RIGHTSIDE

VI.C.--INTERNAL WATER DATA
WATER ELEVATION IN CHAMBER = 395.00 (FT)
WATER ELEVATION IN RIGHTSIDE CULVERT = 395.00 (FT)
WATER ELEVATION IN LEFTSIDE CULVERT = 395.00 (FT)

VII.--ADDITIONAL LOAD DATA
NONE

Figure 54. (Sheet 3 of 3)

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85                                      TIME: 16:43:46

I.--HEADING
  'EXAMPLE 3 - TYPE 31 MONOLITH

     ************************************
     *  RESULTS OF EQUILIBRIUM ANALYSIS  *
     ************************************

 II.--EFFECTS ON STRUCTURE RIGHTSIDE
   II.A.--PRESSURES ON RIGHTSIDE SURFACE
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
     (POSITIVE SHEAR IS DOWN)
     (UNITS ARE POUNDS AND FEET)
```

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
434.500	0.	0.	0.	0.
431.750	0.	0.	0.	0.
429.500	0.	0.	0.	0.
422.000	0.	0.	0.	0.
397.000	0.	0.	0.	1.5625E+03
395.000	1.1500E+02	9.2000E+01	0.	1.6875E+03
392.000	2.8750E+02	2.3000E+02	0.	1.8750E+03
376.000	1.2075E+03	9.6600E+02	0.	2.8750E+03
374.000+	1.3225E+03	1.0580E+03	0.	3.0000E+03
374.000-	1.3225E+03	6.6125E+02	0.	3.0000E+03
358.000	2.3225E+03	1.1613E+03	0.	4.0000E+03

```
   II.B.--PRESSURE ON RIGHTSIDE BASE
     (POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)
```

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	0.	4.0000E+03
5.500	0.	4.0000E+03
11.000	0.	4.0000E+03
16.500	0.	4.0000E+03
22.000	0.	4.0000E+03
27.500	0.	4.0000E+03
33.000	0.	4.0000E+03
38.500	0.	4.0000E+03
44.000	0.	4.0000E+03
50.500	0.	4.0000E+03
55.000	0.	4.0000E+03
55.040	0.	4.0000E+03
59.500	0.	4.0000E+03
63.040	0.	4.0000E+03
64.000	0.	4.0000E+03
68.500	0.	4.0000E+03
73.000	0.	4.0000E+03
77.500	0.	4.0000E+03
79.040	0.	4.0000E+03
82.000	0.	4.0000E+03
86.500	0.	4.0000E+03
88.710	0.	4.0000E+03

Figure 55. Results of equilibrium analysis for Example 3 (Continued)

```
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
  (POSITIVE VERTICAL IS DOWN)
  (POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
  (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER
       FLOOR CENTERLINE)
  (UNITS ARE POUNDS AND FEET)

       ITEM                 HORIZONTAL    VERTICAL      MOMENT
  BACKFILL                  2.4072E+05   0.            -7.8768E+05
  GROUND/SURCH WATER        1.1520E+06   0.             3.8400E+06
  INTERNAL WATER           -1.0153E+05   7.5024E+05   -2.8340E+07
  UPLIFT WATER              0.          -3.1936E+06    1.4165E+08
  CONCRETE                               3.3874E+06   -1.8447E+08
  TOTAL THIS SIDE           1.2912E+06   9.4410E+05   -6.8109E+07

III.--EFFECTS ON STRUCTURE  LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
     (POSITIVE HORIZONTAL IS TO THE RIGHT)
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
     (UNITS ARE POUNDS AND FEET)
          TOTAL HORIZONTAL =   0.
          TOTAL VERTICAL   =   1.8882E+06
          TOTAL MOMENT     =   0.
```

Figure 55. (Concluded)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 16:43:51

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

```
**********************
*  FRAME MODEL DATA  *
**********************
```

II.--RIGHTSIDE FRAME MODEL DATA

II.A.--RIGID BLOCK DATA (FT) - TYPE 31 MONOLITH
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

		<--------------CORNER		LOCATIONS		-------------->	
BLOCK	CORNER NO.	1	2	3	4	5	6	CENTROID
1	X-COORD.	79.04	79.04	88.71	88.71	88.71	79.04	83.87
	ELEVATION	358.00	374.00	374.00	374.00	358.00	358.00	366.00
2	X-COORD.	55.04	55.04	63.04	63.04	63.04	55.04	59.04
	ELEVATION	358.00	376.00	376.00	374.00	358.00	358.00	367.00
3	X-COORD.	55.04	55.04	60.04	63.04	63.04	63.04	59.04
	ELEVATION	392.00	397.00	397.00	397.00	392.00	392.00	394.50
4	X-COORD.	79.04	79.04	88.71	88.71	88.71	88.71	83.88
	ELEVATION	392.00	397.00	397.00	397.00	392.00	392.00	394.50
5	X-COORD.	55.04	55.04	60.04	60.04	60.04	60.04	57.54
	ELEVATION	429.50	434.50	434.50	429.50	429.50	429.50	432.00
6	X-COORD.	83.71	83.71	88.71	88.71	88.71	88.71	86.21
	ELEVATION	429.50	434.50	434.50	431.75	429.50	429.50	432.00

II.B.--JOINT COORDINATES (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

JOINT NO.	X-COORD.	ELEVATION
1	0.00000	367.00000
2	5.50000	367.00000
3	11.00000	367.00000
4	16.50000	367.00000
5	22.00000	367.00000
6	27.50000	367.00000
7	33.00000	367.00000
8	38.50000	367.00000
9	44.00000	367.00000
10	50.50000	367.00000
11	55.00000	367.00000
12	59.04000	367.00000
13	64.00000	366.00000
14	68.50000	366.00000
15	73.00000	366.00000
16	77.50000	366.00000
17	83.87500	366.00000
18	83.87500	394.50000
19	86.21000	432.00000
20	59.04000	394.50000
21	57.54000	432.00000

Figure 56. Frame model data for Example 3 (Sheet 1 of 3)

II.C.--MEMBER DATA (FT)
(NOTE: 'X-COORD.' IS DISTANCE FROM CHAMBER CENTERLINE.)

			<COORDS AT ENDS OF FLEX LENGTH>					
MEM	FROM	TO	<--FROM END-->		<---TO END--->		<-MEMBER DEPTH-->	
NO	JT	JT	X	ELEV	X	ELEV	FROM END	TO END
1	1	2	0.00	367.00	5.50	367.00	18.00	18.00
2	2	3	5.50	367.00	11.00	367.00	18.00	18.00
3	3	4	11.00	367.00	16.50	367.00	18.00	18.00
4	4	5	16.50	367.00	22.00	367.00	18.00	18.00
5	5	6	22.00	367.00	27.50	367.00	18.00	18.00
6	6	7	27.50	367.00	33.00	367.00	18.00	18.00
7	7	8	33.00	367.00	38.50	367.00	18.00	18.00
8	8	9	38.50	367.00	44.00	367.00	18.00	18.00
9	9	10	44.00	367.00	50.50	367.00	18.00	18.00
10	10	11	50.50	367.00	55.00	367.00	18.00	18.00
11	11	12	55.00	367.00	55.04	367.00	18.00	18.00
12	12	13	63.04	366.00	64.00	366.00	16.00	16.00
13	13	14	64.00	366.00	68.50	366.00	16.00	16.00
14	14	15	68.50	366.00	73.00	366.00	16.00	16.00
15	15	16	73.00	366.00	77.50	366.00	16.00	16.00
16	16	17	77.50	366.00	79.04	366.00	16.00	16.00
17	17	18	83.88	374.00	83.88	392.00	9.67	9.67
18	18	19	86.21	397.00	86.21	429.50	5.00	5.00
19	12	20	59.04	376.00	59.04	392.00	8.00	8.00
20	20	21	57.54	397.00	57.54	429.50	5.00	5.00
21	20	18	63.04	394.50	79.04	394.50	5.00	5.00
22	21	19	60.04	432.00	83.71	432.00	5.00	5.00

Figure 56. (Sheet 2 of 3)

II.D.--PILE HEAD STIFFNESS COEFFICIENTS

PILE NO.	X-COORD. (FT)	BATTER (FT/FT)	<-------------STIFFNESS COEFFICIENTS-------------> B11 (LB/FT)	B22 (LB/FT)	B33 (LB-FT)	B13 (LB)
1	0.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
2	5.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
3	11.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
4	16.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
5	22.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
6	27.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
7	38.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
8	50.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
9	59.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
10	68.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
11	73.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
12	77.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
13	82.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
14	86.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
21	0.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
22	5.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
23	11.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
24	16.50	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
25	22.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
26	33.00	0.00	6.5880E+06	2.4000E+08	1.9333E+06	2.7700E+06
27	44.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
28	55.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
29	64.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
30	73.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
31	77.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
32	82.00	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06
33	86.50	0.00	9.8760E+06	2.4000E+08	4.3583E+06	5.0900E+06

III.-- LEFTSIDE FRAME MODEL DATA
SYMMETRIC WITH RIGHTSIDE

Figure 56. (Sheet 3 of 3)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 16:43:57

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

****
* RESULTS OF FRAME ANALYSIS *
****

II.--STRUCTURE DISPLACEMENTS

II.A.--RIGHTSIDE DISPLACEMENTS - TYPE 31 MONOLITH
(POSITIVE HORIZONTAL DISPLACEMENT IS TOWARD CHAMBER CENTERLINE.)
(POSITIVE VERTICAL DISPLACEMENT IS DOWN.)
(POSITIVE ROTATION IS COUNTERCLOCKWISE.)

JT NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<----DISPLACEMENT (FT OR RADIANS)----> HORIZONTAL	VERTICAL	ROTATION
		***** BASE JOINTS *****			
1	0.00	367.00	0.	-2.339E-05	0.
2	5.50	367.00	9.011E-05	-1.975E-05	-1.565E-06
3	11.00	367.00	1.803E-04	-8.092E-06	-3.245E-06
4	16.50	367.00	2.708E-04	1.367E-05	-5.096E-06
5	22.00	367.00	3.615E-04	4.871E-05	-7.046E-06
6	27.50	367.00	4.527E-04	1.007E-04	-8.805E-06
7	33.00	367.00	5.442E-04	1.674E-04	-9.846E-06
8	38.50	367.00	6.360E-04	2.469E-04	-9.584E-06
9	44.00	367.00	7.284E-04	3.343E-04	-7.216E-06
10	50.50	367.00	8.383E-04	4.314E-04	-7.556E-08
11	55.00	367.00	9.149E-04	4.823E-04	8.709E-06
12	59.04	367.00	9.156E-04	4.475E-04	8.803E-06
13	64.00	366.00	9.217E-04	4.002E-04	1.019E-05
14	68.50	366.00	9.918E-04	3.477E-04	1.660E-05
15	73.00	366.00	1.063E-03	2.843E-04	2.404E-05
16	77.50	366.00	1.135E-03	2.133E-04	3.413E-05
17	83.87	366.00	1.160E-03	-9.294E-07	3.850E-05
		***** OUTSIDE STEM JOINTS *****			
18	83.88	394.50	3.189E-03	1.899E-04	6.475E-05
19	86.21	432.00	7.025E-03	3.898E-04	8.867E-05
		***** INSIDE STEM JOINTS *****			
20	59.04	394.50	3.022E-03	7.930E-04	1.110E-04
21	57.54	432.00	6.996E-03	1.355E-03	7.228E-06

II.B.-- LEFTSIDE DISPLACEMENTS - TYPE 31 MONOLITH
SYMMETRIC WITH RIGHTSIDE

Figure 57. Results of frame analysis for Example 3 (Sheet 1 of 5)

III.--FORCES AT ENDS OF MEMBERS
(MEMBER FORCES ARE GIVEN AT ENDS OF FLEXIBLE LENGTH.)

III.A.--RIGHTSIDE MEMBERS - TYPE 31 MONOLITH
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR FORCE TENDS TO MOVE MEMBER UPWARD OR TOWARD CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON TOP OF MEMBER OR ON SIDE OF MEMBER TOWARD CHAMBER CENTERLINE.)

MEM NO	DISTANCE FROM CHAMB CL (FT)	ELEVATION (FT)	<--------FORCES (LBS OR LB-FT)-------> AXIAL	SHEAR	MOMENT
		***** BASE MEMBERS *****			
1	0.00	367.00	1.147E+06	-5.614E+03	-5.275E+05
	5.50	367.00	1.147E+06	4.505E+01	-5.431E+05
2	5.50	367.00	1.148E+06	-9.524E+03	-5.561E+05
	11.00	367.00	1.148E+06	3.955E+03	-5.931E+05
3	11.00	367.00	1.151E+06	-7.839E+03	-6.193E+05
	16.50	367.00	1.151E+06	2.270E+03	-6.471E+05
4	16.50	367.00	1.155E+06	4.290E+03	-6.867E+05
	22.00	367.00	1.155E+06	-9.859E+03	-6.478E+05
5	22.00	367.00	1.161E+06	3.324E+04	-7.009E+05
	27.50	367.00	1.161E+06	-3.881E+04	-5.028E+05
6	27.50	367.00	1.164E+06	6.298E+04	-5.360E+05
	33.00	367.00	1.164E+06	-6.855E+04	-1.743E+05
7	33.00	367.00	1.168E+06	1.087E+05	-2.139E+05
	38.50	367.00	1.168E+06	-1.143E+05	3.994E+05
8	38.50	367.00	1.175E+06	1.735E+05	3.310E+05
	44.00	367.00	1.175E+06	-1.791E+05	1.301E+06
9	44.00	367.00	1.183E+06	2.593E+05	1.226E+06
	50.50	367.00	1.183E+06	-2.659E+05	2.933E+06
10	50.50	367.00	1.192E+06	3.694E+05	2.854E+06
	55.00	367.00	1.192E+06	-3.740E+05	4.527E+06
11	55.00	367.00	1.200E+06	4.897E+05	4.449E+06
	55.04	367.00	1.200E+06	-4.898E+05	4.468E+06
12	63.04	366.00	9.619E+05	-6.822E+04	1.948E+06
	64.00	366.00	9.619E+05	6.573E+04	1.883E+06
13	64.00	366.00	9.701E+05	3.032E+04	1.813E+06
	68.50	366.00	9.701E+05	-4.197E+04	1.976E+06
14	68.50	366.00	9.785E+05	1.254E+05	1.904E+06
	73.00	366.00	9.785E+05	-1.371E+05	2.495E+06
15	73.00	366.00	9.955E+05	2.735E+05	2.351E+06
	77.50	366.00	9.955E+05	-2.852E+05	3.608E+06
16	77.50	366.00	1.012E+06	3.876E+05	3.466E+06
	79.04	366.00	1.012E+06	-3.915E+05	4.066E+06

Figure 57. (Sheet 2 of 5)

		***** OUTSIDE STEM MEMBERS *****			
17	83.88	374.00	5.160E+05	-4.098E+05	2.882E+06
	83.88	392.00	2.811E+05	3.208E+04	-8.939E+05
18	86.21	397.00	3.197E+05	-1.525E+05	8.344E+05
	86.21	429.50	1.003E+05	-2.330E+04	1.267E+05
		***** INSIDE STEM MEMBERS *****			
19	59.04	376.00	7.580E+05	-2.237E+05	2.849E+06
	59.04	392.00	5.852E+05	2.237E+05	-7.302E+05
20	57.54	397.00	3.463E+05	-2.330E+04	2.493E+05
	57.54	429.50	1.269E+05	2.330E+04	-5.079E+05
		***** CULVERT ROOF *****			
21	63.04	394.50	2.029E+05	1.849E+05	-1.380E+06
	79.04	394.50	2.029E+05	-1.039E+05	9.305E+05
		***** VOID ROOF *****			
22	60.04	432.00	2.330E+04	9.318E+04	-3.332E+05
	83.71	432.00	2.330E+04	6.659E+04	-1.845E+04

III.B.-- LEFTSIDE MEMBERS - TYPE 31 MONOLITH
SYMMETRIC WITH RIGHTSIDE

Figure 57. (Sheet 3 of 5)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 16:43:57

I.--HEADING
'EXAMPLE 3 - TYPE 31 MONOLITH

II.--RESULTS FOR RIGHTSIDE PILES

II.A.--PILE HEAD FORCES AND DISPLACEMENTS
(UNITS ARE POUNDS, FEET, AND RADIANS.)
(POSITIVE AXIAL FORCE IS COMPRESSION.)
(POSITIVE SHEAR TENDS TO MOVE PILE HEAD AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE MOMENT PRODUCES COMPRESSION ON SIDE OF PILE TOWARD CHAMBER CENTERLINE.)
(POSITIVE AXIAL DISPLACEMENT IS DOWN.)
(POSITIVE LATERAL DISPLACEMENT IS AWAY FROM CHAMBER CENTERLINE.)
(POSITIVE ROTATION TENDS TO ROTATE PILE HEAD TOWARD CHAMBER CENTERLINE.)

PILE	DIST. TO	<-------PILE HEAD FORCES------->			<---PILE HEAD DISPLACEMENTS---->		
NO.	CHAMB CL	AXIAL	SHEAR	MOMENT	AXIAL	LATERAL	ROTATION
1	0.00	-5.614E+03	0.	0.	-2.339E-05	0.	0.
2	5.50	-4.739E+03	-6.908E+02	-2.917E+02	-1.975E-05	-1.042E-04	-1.565E-06
3	11.00	-1.942E+03	-1.389E+03	-5.867E+02	-8.092E-06	-2.095E-04	-3.245E-06
4	16.50	3.280E+03	-2.100E+03	-8.869E+02	1.367E-05	-3.166E-04	-5.096E-06
5	22.00	1.169E+04	-2.819E+03	-1.191E+03	4.871E-05	-4.249E-04	-7.046E-06
6	27.50	2.417E+04	-3.529E+03	-1.491E+03	1.007E-04	-5.320E-04	-8.805E-06
7	38.50	5.925E+04	-7.182E+03	-3.718E+03	2.469E-04	-7.223E-04	-9.584E-06
8	50.50	1.035E+05	-8.286E+03	-4.271E+03	4.314E-04	-8.390E-04	-7.556E-08
9	59.50	1.064E+05	-8.215E+03	-4.219E+03	4.435E-04	-8.364E-04	8.803E-06
10	68.50	8.345E+04	-8.400E+03	-4.300E+03	3.477E-04	-8.591E-04	1.660E-05
11	73.00	6.824E+04	-8.473E+03	-4.325E+03	2.843E-04	-8.703E-04	2.404E-05
12	77.50	5.118E+04	-8.336E+03	-4.237E+03	2.133E-04	-8.616E-04	3.413E-05
13	82.00	1.710E+04	-8.216E+03	-4.167E+03	7.125E-05	-8.517E-04	3.850E-05
14	86.50	-2.448E+04	-8.216E+03	-4.167E+03	-1.020E-04	-8.517E-04	3.850E-05
21	0.00	-5.614E+03	0.	0.	-2.339E-05	0.	0.
22	5.50	-4.739E+03	-6.908E+02	-2.917E+02	-1.975E-05	-1.042E-04	-1.565E-06
23	11.00	-1.942E+03	-1.389E+03	-5.867E+02	-8.092E-06	-2.095E-04	-3.245E-06
24	16.50	3.280E+03	-2.100E+03	-8.869E+02	1.367E-05	-3.166E-04	-5.096E-06
25	22.00	1.169E+04	-2.819E+03	-1.191E+03	4.871E-05	-4.249E-04	-7.046E-06
26	33.00	4.017E+04	-4.196E+03	-1.772E+03	1.674E-04	-6.328E-04	-9.846E-06
27	44.00	8.022E+04	-7.872E+03	-4.070E+03	3.343E-04	-7.934E-04	-7.216E-06
28	55.00	1.158E+05	-8.218E+03	-4.220E+03	4.823E-04	-8.366E-04	8.709E-06
29	64.00	9.605E+04	-8.246E+03	-4.232E+03	4.002E-04	-8.402E-04	1.019E-05
30	73.00	6.824E+04	-8.473E+03	-4.325E+03	2.843E-04	-8.703E-04	2.404E-05
31	77.50	5.118E+04	-8.336E+03	-4.237E+03	2.133E-04	-8.616E-04	3.413E-05
32	82.00	1.710E+04	-8.216E+03	-4.167E+03	7.125E-05	-8.517E-04	3.850E-05
33	86.50	-2.448E+04	-8.216E+03	-4.167E+03	-1.020E-04	-8.517E-04	3.850E-05

II.B.--PILE ALLOWABLES COMPARISONS
ALLOWABLES DATA NOT PROVIDED FOR THIS SIDE.

III.--RESULTS FOR LEFTSIDE PILES
SYMMETRIC WITH RIGHTSIDE.

Figure 57. (Sheet 4 of 5)

IV.--RESULTANTS OF PILE FORCES ON STRUCTURE
(POSITIVE HORIZONTAL IF TO THE RIGHT)
(POSITIVE VERTICAL IS UP)
(POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE
(UNITS ARE POUNDS AND FEET)

	HORIZONTAL	VERTICAL	MOMENT
RIGHTSIDE PILES	1.4462E+05	9.4410E+05	5.7262E+07
LEFTSIDE PILES	-1.4462E+05	9.4410E+05	-5.7262E+07
TOTAL	0.	1.8882E+06	0.

NOTE: RIGHTSIDE AND LEFTSIDE RESULTANTS INCLUDE ONE HALF OF FORCES FOR VERTICAL PILES ON CHAMBER CENTERLINE.

Figure 57. (Sheet 5 of 5)

Example 4--Nonconforming Monolith

147. The monolith shown in Figure 58 does not conform to the geometric requirements for frame analysis for type 2 or type 3 monoliths. However, this geometry is admissible for equilibrium analysis.

148. The predefined input file for the symmetric, soil-supported system is shown in Figure 59 and an echoprint of input is given in Figure 60. The results of the equilibrium analysis are given in Figure 61.

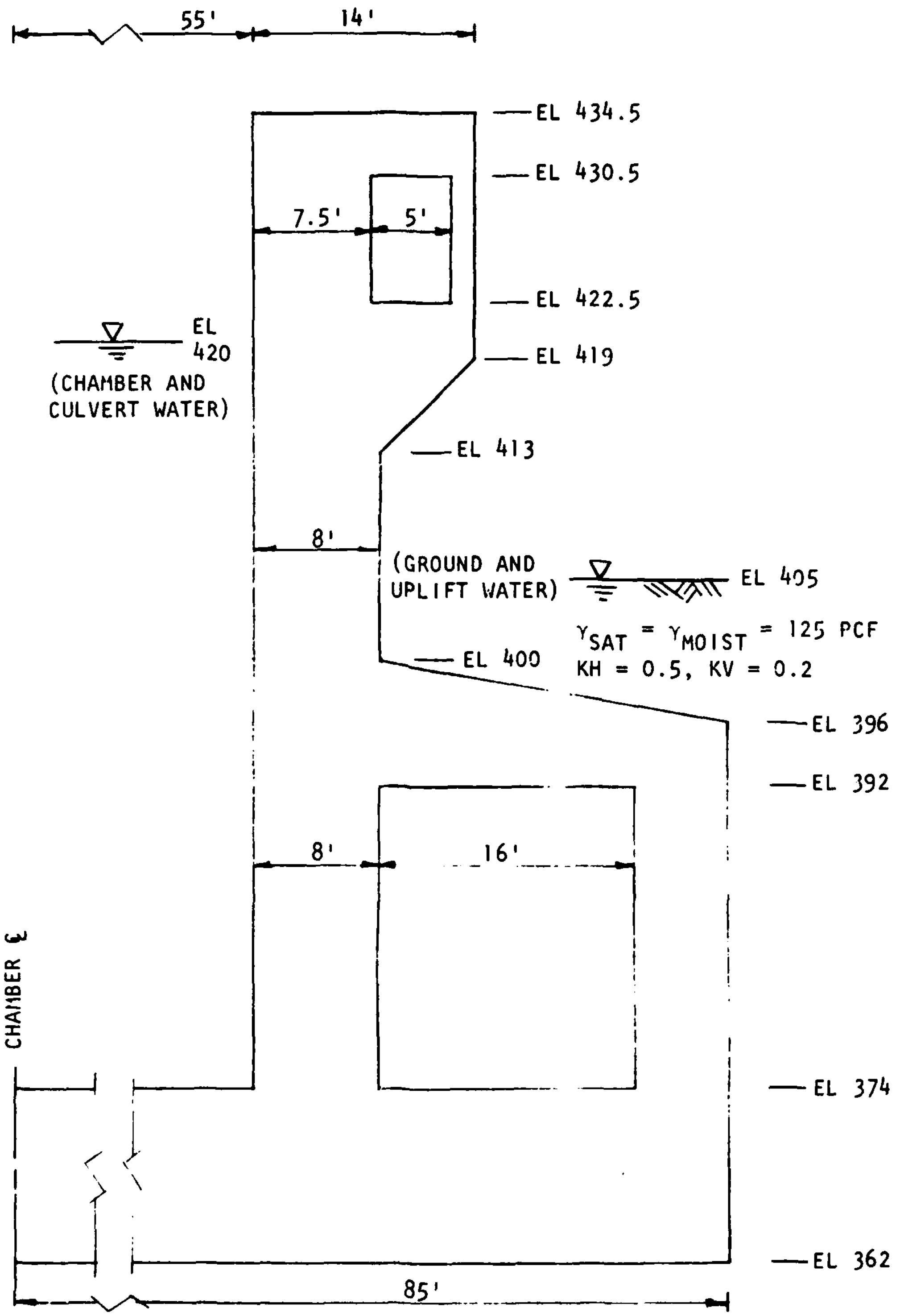


Figure 58. System for Example 4

***** INPUT FILE FOR EXAMPLE 4 *****

```
1000 'EXAMPLE 4 - NONCONFORMING MONOLITH
1010 METHOD EQUILIBRIUM
1020 STRUCTURE 3.E6 .2 150 1
1030 FLOOR 55 374 0
1040 BASE BOTH 85 362
1050 STEM BOTH 5 14 434.5 14 419
1060 8 413 8 400 30 396
1070 CULVERT BOTH 8 16 374 18 0
1080 VOID BOTH 7.5 5 422.5 8 0
1090 BACKFILL BOTH SOIL 1 0
1100 405 125 125 .5 .5 .2 .2
1110 REACTION SOIL TRAPEZOIDAL .5
1120 WATER 62.5
1130 INTERNAL 420 420 420
1140 EXTERNAL BOTH ELEVATION 405
1150 UPLIFT ELEVATION 405 405
1160 FINISH
```

Figure 59. Input file for Example 4

```
PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85                                    TIME: 17:28:25

I.--HEADING
  'EXAMPLE 4 - NONCONFORMING MONOLITH

              ****************
              *  INPUT DATA  *
              ****************

II.--EQUILIBRIUM ANALYSIS ONLY

III.--STRUCTURE DATA

  III.A.--MATERIAL PROPERTIES
     MODULUS OF ELASTICITY OF CONCRETE  =     3.000E+06 (PSI)
     POISSON'S RATIO FOR CONCRETE       =      .20
     UNIT WEIGHT OF CONCRETE            =  150.0     (PCF)
     THICKNESS OF TWO-DIMENSIONAL SLICE =    1.00    (FT)

  III.B.--FLOOR DATA
     FLOOR WIDTH        =       55.00 (FT)
     FLOOR ELEVATION    =      374.00 (FT)
     FLOOR FILLET SIZE  =        0.00 (FT)

  III.C.--BASE DATA

    III.C.1.--RIGHTSIDE
     DISTANCE FROM
      CHAMBER CL      ELEVATION
          (FT)           (FT)
          85.00         362.00

    III.C.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.

  III.D.--STEM DATA

    III.D.1.--RIGHTSIDE
     DISTANCE FROM
       STEM FACE      ELEVATION
          (FT)           (FT)
          14.00         434.50
          14.00         419.00
           8.00         413.00
           8.00         400.00
          30.00         396.00

    III.D.2.--LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE.
```

Figure 60. Echoprint of input data for Example 4 (Continued)

```
III.E.--CULVERT DATA
  III.E.1.--RIGHTSIDE
   DISTANCE FROM STEM FACE TO INTERIOR SIDE =       8.00 (FT)
   CULVERT WIDTH                            =      16.00 (FT)
   ELEVATION AT CULVERT FLOOR               =     374.00 (FT)
   CULVERT HEIGHT                           =      18.00 (FT)
   CULVERT FILLET SIZE                      =       0.00 (FT)
  III.E.2.--LEFTSIDE
   SYMMETRIC WITH RIGHTSIDE

III.F.--VOID DATA
  III.F.1.--RIGHTSIDE
   DISTANCE FROM STEM FACE TO INTERIOR SIDE =       7.50 (FT)
   VOID WIDTH                               =       5.00 (FT)
   ELEVATION AT VOID BOTTOM                 =     422.50 (FT)
   VOID HEIGHT                              =       8.00 (FT)
   VOID TIES                                   NONE
  III.F.2.--LEFTSIDE
   SYMMETRIC WITH RIGHTSIDE

IV.--BACKFILL DATA
  IV.A.--RIGHTSIDE SOIL LAYER DATA (SURFACE SURCHARGE =      0.00 (PSF))
   ELEV                                <-PRESSURE COEFFICIENTS->
    AT     SATURATED     MOIST      HORIZONTAL        SHEAR
   TOP      UNIT WT.    UNIT WT.    TOP    BOT.      TOP    BOT.
   (FT)      (PCF)       (PCF)
  405.00     125.0       125.0      .500   .500      .200   .200
  IV.B.--LEFTSIDE SOIL LAYER DATA
   SYMMETRIC WITH RIGHTSIDE

V.--BASE REACTION DATA
   REACTION PROVIDED BY TRAPEZOIDAL SOIL PRESSURE DISTRIBUTION
   FRACTION OF UNIFORM BASE PRESSURE AT CENTERLINE =      .50

VI.--WATER DATA
   WATER UNIT WEIGHT =  62.5 (PCF)
  VI.A.--EXTERNAL WATER DATA
   VI.A.1.--RIGHTSIDE EXTERNAL WATER DATA
   GROUND-WATER ELEVATION     =     405.00 (FT)
   SURCHARGE WATER                   NONE
   VI.A.2.-- LEFTSIDE EXTERNAL WATER DATA
   SYMMETRIC WITH RIGHTSIDE
  VI.B.--UPLIFT WATER DATA
   RIGHTSIDE UPLIFT WATER ELEVATION =     405.00 (FT)
   LEFTSIDE UPLIFT WATER ELEVATION  =     405.00 (FT)
  VI.C.--INTERNAL WATER DATA
   WATER ELEVATION IN CHAMBER            =     420.00 (FT)
   WATER ELEVATION IN RIGHTSIDE CULVERT =     420.00 (FT)
   WATER ELEVATION IN LEFTSIDE CULVERT  =     420.00 (FT)

VII.--ADDITIONAL LOAD DATA
   NONE
```

Figure 60. (Concluded)

PROGRAM CUFRAM - ANALYSIS OF TWO-DIMENSIONAL U-FRAME STRUCTURES
DATE: 09/18/85 TIME: 17:28:35

I.--HEADING
EXAMPLE 4 - NONCONFORMING MONOLITH

```
*************************************
*  RESULTS OF EQUILIBRIUM ANALYSIS  *
*************************************
```

II.--EFFECTS ON STRUCTURE RIGHTSIDE

II.A.--PRESSURES ON RIGHTSIDE SURFACE
(POSITIVE VERTICAL IS DOWN)
(POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
(POSITIVE SHEAR IS DOWN)
(UNITS ARE POUNDS AND FEET)

	<---------BACKFILL PRESSURE--------->			GRND/SURCH
ELEVATION	VERTICAL	HORIZONTAL	SHEAR	WATER PRESSURE
434.500	0.	0.	0.	0.
430.500	0.	0.	0.	0.
422.500	0.	0.	0.	0.
420.000	0.	0.	0.	0.
419.000	0.	0.	0.	0.
413.000	0.	0.	0.	0.
405.000	0.	0.	0.	0.
400.000	3.1250E+02	1.5625E+02	6.2500E+01	3.1250E+02
396.000	5.6250E+02	2.8125E+02	1.1250E+02	5.6250E+02
392.000	8.1250E+02	4.0625E+02	1.6250E+02	8.1250E+02
374.000	1.9375E+03	9.6875E+02	3.8750E+02	1.9375E+03
362.000	2.6875E+03	1.3438E+03	5.3750E+02	2.6875E+03

II.B.--PRESSURE ON RIGHTSIDE BASE
(POSITIVE PRESSURE IS UP; UNITS ARE POUNDS AND FEET)

DIST FROM CHAMBER CL	SOIL REACTION PRESSURE	UPLIFT WATER PRESSURE
0.000	1.4750E+03	2.6875E+03
55.000	3.3837E+03	2.6875E+03
63.000	3.6614E+03	2.6875E+03
79.000	4.2167E+03	2.6875E+03
85.000	4.4249E+03	2.6875E+03

Figure 61. Results of equilibrium analysis for Example 4 (Continued)

```
II.C.--RESULTANTS OF LOADS ON STRUCTURE RIGHTSIDE
   (POSITIVE VERTICAL IS DOWN)
   (POSITIVE HORIZONTAL IS TOWARD CHAMBER CENTERLINE)
   (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER
        FLOOR CENTERLINE)
   (UNITS ARE POUNDS AND FEET)

        ITEM               HORIZONTAL    VERTICAL       MOMENT
   BACKFILL                3.0816E+04   2.1181E+04  -1.5844E+06
   GROUND/SURCH WATER      5.7781E+04   9.6250E+03  -5.8751E+05
   INTERNAL WATER         -6.6125E+04   1.7613E+05  -6.6404E+06
   UPLIFT WATER            0.          -2.2844E+05   9.7086E+06
   SOIL BASE REACT         0.          -2.5074E+05   1.2433E+07
   CONCRETE                             2.7225E+05  -1.4262E+07
   TOTAL THIS SIDE         2.2472E+04   0.          -9.3251E+05

III.--EFFECTS ON STRUCTURE  LEFTSIDE
     SYMMETRIC WITH RIGHTSIDE

IV.--NET RESULTANTS OF ALL LOADS
     (POSITIVE HORIZONTAL IS TO THE RIGHT)
     (POSITIVE VERTICAL IS DOWN)
     (POSITIVE MOMENT IS COUNTERCLOCKWISE ABOUT CHAMBER FLOOR CENTERLINE)
     (UNITS ARE POUNDS AND FEET)
          TOTAL HORIZONTAL =   0.
          TOTAL VERTICAL   =   0.
          TOTAL MOMENT     =   0.
```

Figure 61. (Concluded)

APPENDIX A: GUIDE FOR DATA INPUT

Source of Input

1. Input data may be supplied from a predefined data file or from the user terminal during execution. If data are supplied from the user terminal, prompting messages are printed to indicate the amount and character of data to be entered.

Data Editing

2. When all data for a problem have been entered, the user is offered the opportunity to review an echoprint of the currently available input data and to revise any or all sections of the input data before execution is attempted. When data are edited during execution, each section must be entered in its entirety.

Input Data File Generation

3. After data have been entered from the terminal, initially or after editing, the user may direct the program to write the input data to a permanent file in input data file format.

Data Format

4. All input data (supplied from the user terminal or from a file) are read in free field format:

a. Data items must be separated by one or more blanks (comma separators are not permitted).

b. Integer numbers must be of form NNNN.

c. Real numbers may be of form

±xxxx, ±xx.xx, or ±xx.xxE+ee

d. User responses to all requests for control by the program for alphanumeric input may be abbreviated by the first letter of the indicated word response, e.g.,

ENTER 'YES' OR 'NO'--respond Y or N

ENTER 'CONTINUE' OR 'END'--respond C or E

5. Input data are divided into the sections shown in Figure A1.

I. Heading (Required)

II. Control (Required)

III. Structure Data

- A. Control (Required)
- B. Floor Data (Required)
- C. Stem Data (Required)
- D. Culvert Data (Optional)
- E. Void Data (Optional)

IV. Backfill Data (Optional)

V. Base Reaction Data (Required)

VI. Water Data (Optional)

VII. Additional Load Data (Optional)

VIII. Termination (Required)

Figure A1. Sections of input data

6. When data are entered from the terminal, prompts indicate the data items to be provided.

Units

7. The program expects data to be provided in units of inches, feet, pounds, or kips as noted in the following guide. No provision is made for conversion of units by the program.

Predefined Data File

8. In addition to the general format requirements given in paragraph 4 of this appendix, the following pertain to a predefined data file and to the input data description beginning in paragraph 12.

- a. Each line must commence with a nonzero, positive line number, denoted LN below.
- b. A line of input may require both alphanumeric and numeric data items. Alphanumeric data items are enclosed in single quotes in the following paragraphs.
- c. A line of input may require a keyword. The acceptable abbreviation for the keyword is indicated by underlined capital letters,

e.g., the acceptable abbreviation for the keyword 'PROperties' is 'PRO'.

d. Lower case words in single quotes indicate definitions of a choice of keywords follows.

e. Items designated by upper case letters and numbers without quotes indicate numeric data values. Numeric data values are real or integer, according to standard FORTRAN variable naming conventions.

f. Data items enclosed in brackets [ ] may not be required. Data items enclosed in braces { } indicate special note follows.

g. Input data are divided into the sections discussed in paragraph 5. Except for the heading, each section consists of a header line and one or more data lines.

h. Comment lines may be inserted in the input file by enclosing the line, following the line number, in parentheses. Comment lines are ignored, e.g.,

    1234b̸ (THIS LINE IS IGNORED).

Sequence of Solutions

9. A predefined data file may contain a sequence of input data sets to be run in succession. Each data set must contain all required data (from heading through termination) for the problem and be independent of all other problems in the sequence. All output data for a sequence of solutions are directed to a permanent file which must be retrieved after termination of execution. Data editing during execution is not available when a sequence of solutions is run.

General Discussion of Input Data

10. Each data section contains a descriptor {'side'} to indicate the side of the structure to which the data apply. For symmetric effects ('side' = 'Both'), the data section is entered only once and symmetric data are applied to both sides automatically. For unsymmetric conditions, except for pile data, the description for the rightside* (if present) must be entered first and must be immediately followed by the description for the leftside* (if present). In the case of pile data, all pile data subsections must be

---

* The terms "rightside" and "leftside" are each used in a one-word form in the text to be consistent with these terms as used in the computer program.

entered for the rightside first, followed by all pile data subsections for the leftside.

11. Rightside and leftside descriptions must be supplied explicitly or implicitly (i.e., 'side' = 'Both') for STRUCTURE and BASE REACTION data sections. All other data may be supplied for the rightside or leftside, both sides, or may be omitted entirely.

Input Description

12. CONTROL--Two (2) to five (5) lines.

a. Heading--One (1) to four (4) lines.

(1) Line contents

LN {'heading'}

(2) Definition

'heading' = any alphanumeric information up to 70 characters including LN and any embedded blanks. First nonblank character following LN must be a single quote (').

b. Method--One (1) line.

(1) Line contents

LN 'Method' {'mode'} [RLF]

(2) Definitions

'Method' = keyword

'mode' = 'Equilibrium' if only pressure and resultant force evaluation required.

= 'Frame' if equilibrium analysis and 2-D plane frame analysis required

[RLF] = rigid block reduction factor for member flexible lengths ($0 \leq RLF \leq 1$). Omit if 'mode' = 'Equilibrium'.

(3) Discussion

For 'mode' = 'Frame', the structure geometry must conform to one of the six types of monoliths described in Part V.

13. STRUCTURE

a. Control--One (1) line.

(1) Line contents

LN 'Structure' EC PR WTCONC [SLICE]

(2) Definitions

'Structure' = keyword

EC = modulus of elasticity of concrete (PSI)

PR = Poisson's ratio for concrete ($0 \le PR < 0.5$)

WTCONC = unit weight of concrete (PCF)

[SLICE] = thickness of slice of structure to be considered (FT); assumed to be one (1) ft if omitted

(3) Discussion

Any width of slice of structure to be analyzed may be used. If this item is omitted, a 1-ft slice is assumed. A slice width other than 1-ft may facilitate describing other effects (e.g., pile foundation) on the structure.

b. Floor data--One (1) line.

(1) Line contents

LN 'Floor' FLRWID ELFLOR [FLRFIL]

(2) Definitions

'Floor' = keyword

FLRWID = distance from chamber centerline* to inside face of stem (FT)

ELFLOR = elevation of chamber floor (FT)

[FLRFIL] = width of 45-deg fillet at floor-stem intersection (FT); assumed to be zero if omitted

(3) Discussion

(a) All 'Floor' and 'Base' distances are measured from the centerline of the chamber; i.e, from midpoint between interior stem faces.

(b) Identical 45-deg fillets are assumed to exist in both corners of the chamber floor.

c. Base data--One (1) or two (2) lines

(1) Line contents

LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]

(2) Definitions

'Base' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

---

* The term "centerline" is used in a one-word form in the text to be consistent with the term as used in the computer program.

DBASE(1) = distance from chamber centerline to first base point (FT)

ELBASE(1) = elevation at first base point (FT)

[DBASE(2), ELBASE(2)] = distance from chamber centerline to second base point (FT) and elevation (FT) at second base point; both may be omitted

(3) Discussion

(a) See Figure A2 for notation.

(b) Base points, define locations where changes in slope of the base occur. Up to two (2) points may be defined on either side of the chamber centerline. The base is assumed to be horizontal from the chamber centerline to the first point and is assumed to be straight between input points.

(c) If only one base point is provided, DBASE(1) must be greater than zero.

(d) If two points are provided, the following must be satisfied:

DBASE(1) ≥ 0

DBASE(2) > DBASE(1)

(e) Distances and elevations for some data items in subsequent sections are restricted by the base dimensions. For reference the limits are expressed in terms of DBASE(2) and ELBASE(2). If only one base point has been provided, DBASE(2) = DBASE(1) and ELBASE(2) = ELBASE(1).

(f) If {'side'} = 'Both', identical base point data are assigned to both sides of the structure base.

(g) If 'Rightside' and 'Leftside' base data differ, 'Rightside' ELBASE(1) must be equal to 'Leftside' ELBASE(1). Enter 'Rightside' base data first and immediately follow with 'Leftside' data.

d. Stem data--One (1) to four (4) lines

(1) Line contents

LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1)...

[LN ... DSTEM(NPTS) ELSTEM(NPTS)]

(Continue DSTEM, ELSTEM pairs on second line following line number until NPTS pairs provided)

(2) Definitions

'Stem' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

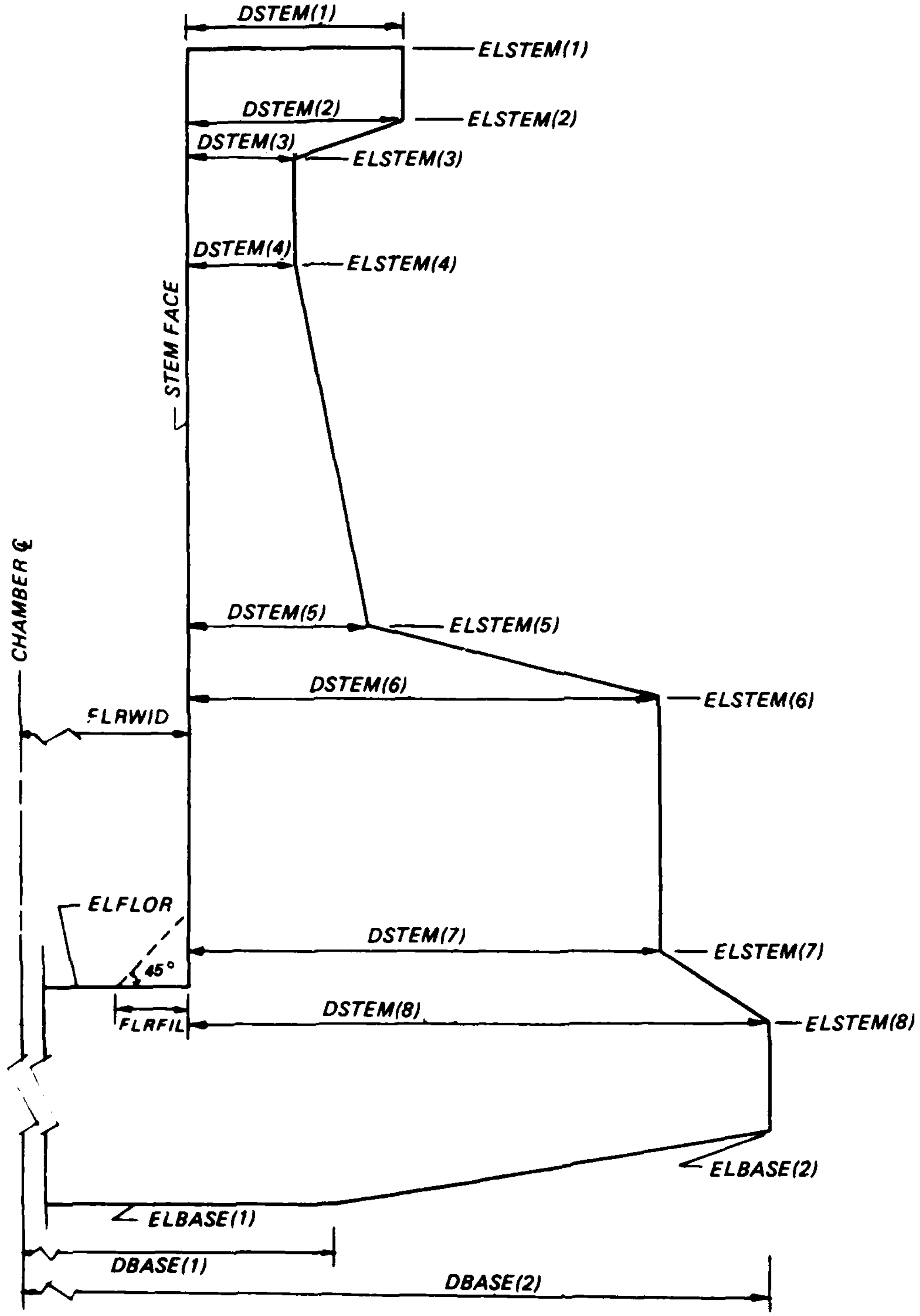


Figure A2. Stem and base

NPTS = number (1 to 8) of stem points

DSTEM(I) = distance from inside face of stem to i^{th} stem point (FT)

ELSTEM(I) = elevation at i^{th} stem point (FT)

(3) Discussion

(a) See Figure A2 for notation.

(b) If {'side'} = 'Both', identical stems are assumed.

(c) DSTEM, ELSTEM pairs must start at top of stem and proceed sequentially downward with:

$$DSTEM(1) > 0$$

$$ELSTEM(I) \le ELSTEM(I - 1)$$

$$ELSTEM(NPTS) > ELBASE(2)$$

(d) The top of the stem is assumed to be horizontal at ELSTEM(1).

(e) Successive stem points are assumed to be connected by straight lines.

(f) The last stem point provided is connected by a straight line to the last base point provided.

(g) If 'mode' = 'Frame', the number of stem points and locations of stem points must conform to limitations described in Part V.

(h) If 'Rightside' and 'Leftside' stem geometries differ, enter 'Rightside' data first and immediately follow with 'Leftside' data.

e. Culvert data--Zero (0), one (1), or two (2) lines, entire section may be omitted

(1) Line contents

[LN 'Culvert' {'side'} DCUL CULWID ELCUL CULHGT [CULFIL]]

(2) Definitions

'Culvert' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DCUL = distance from inside stem face to interior vertical side of culvert (FT)

CULWID = width of culvert opening (FT)

ELCUL = elevation of floor of culvert (FT)

CULHGT = height of culvert opening (FT)

[CULFIL] = width of 45-deg fillet in culvert corners (FT); assumed to be zero if omitted

(3) Discussion

(a) See Figure A3 for notation.

(b) If {'side'} = 'Both', identical culverts are assigned to both sides of the structure.

(c) If culvert data are provided for one side only, no culvert is assumed for the opposite side.

(d) A rectangular culvert is assumed. Culvert dimensions must result in the culvert opening lying entirely within the external boundaries defined by stem and base data.

(e) Identical fillets are assumed in all four corners of the culvert except when stem void floor (see next section) coincides with the top of the culvert. In this case, fillets in top corners are omitted.

(f) If different culverts occur on each side, enter 'Rightside' data first and immediately follow with 'Leftside' data.

(g) If 'mode' = 'Frame', culvert locations must conform to limitation described in Part V.

f. Stem void data--Zero (0) or one (1) to four (4) lines, entire section may be omitted

(1) Line 1 contents

[LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT [NTIES]

(2) Line 2 contents (omit if NTIES = 0)

[LN ELTIE(1) HTIE(1) ELTIE(2) HTIE(2) ... ELTIE(NTIES) HTIE(NTIES)]

(3) Definitions

'Void' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

DVOID = distance from inside stem fact to interior vertical side of void (FT)

VOIDWD = width of void opening (FT)

ELVOID = elevation of bottom of void opening (FT)

VOIDHT = height of void opening (FT)

NTIES = number of horizontal structural members across void opening (0 to 5)

ELTIE(I) = elevation at top of i^{th} tie member (FT)

HTIE(I) = depth of i^{th} tie member (FT)

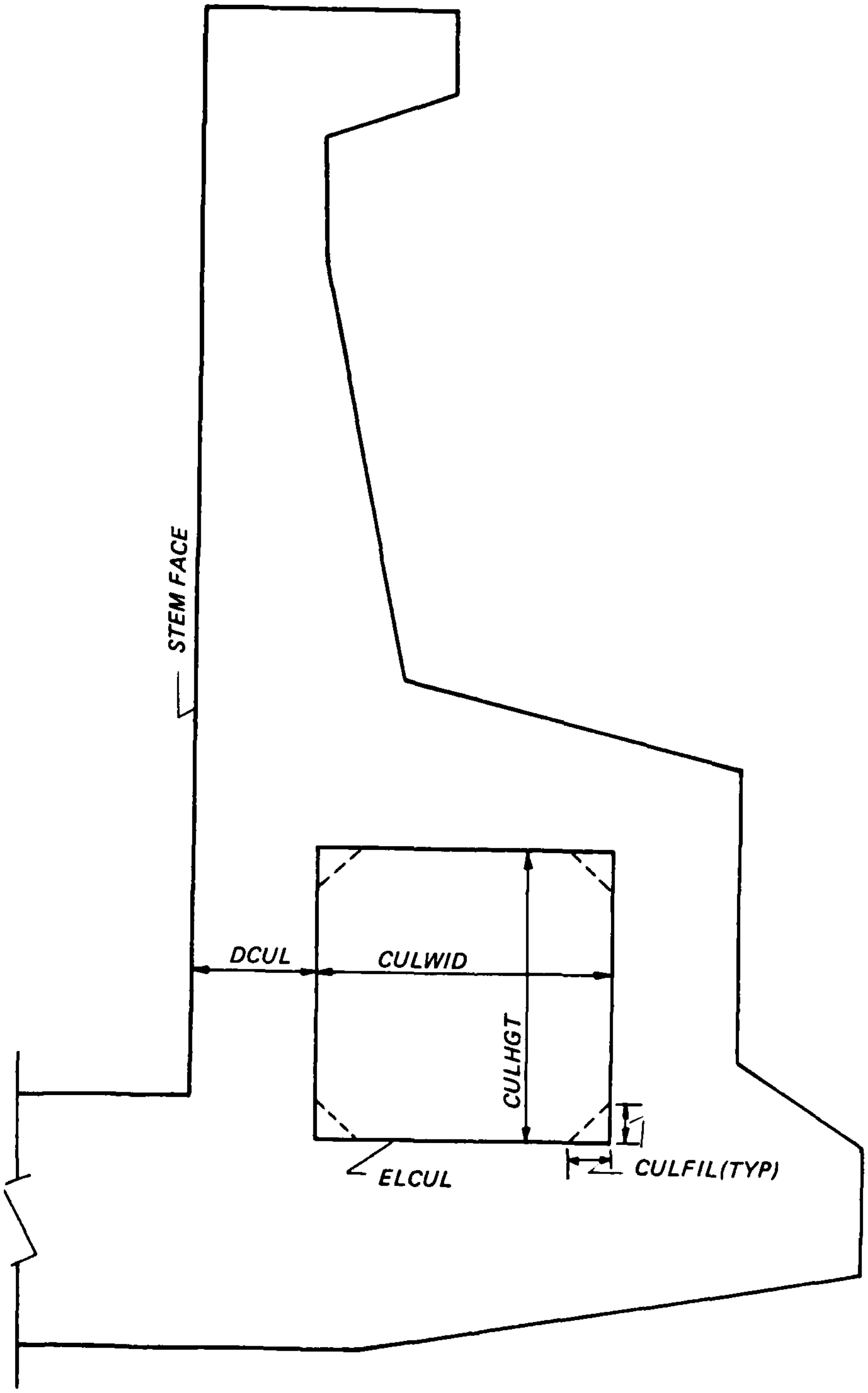


Figure A3. Culvert

(4) Discussion

(a) See Figure A4 for notation.

(b) If {'side'} = 'Both', identical voids (and ties) are assumed to exist in stems on both sides.

(c) If void (and tie) data are provided for one side only no void is assumed in the opposite stem.

(d) The void is assumed to be a rectangular opening and must lie entirely within the external boundaries defined by the stem and base data.

(e) Void data must satisfy the following:

ELVOID ≥ (ELCUL + CULHGT) if culvert present

(ELVOID + VOIDHT) ≤ ELSTEM(1).

(f) If ELVOID = (ELCUL + CULHGT), the top of the culvert is assumed to be open to the void and culvert fillets are omitted in the top corners of the culvert.

(g) If (ELVOID + VOIDHT) < ELSTEM(1), the void is treated as an additional rectangular opening in the stem.

(h) The void is assumed to be free of interior water unless the void is connected to the culvert.

(i) If 'mode' = 'Frame', a void may not exist in the stem unless a culvert is also present.

(j) Void ties are intended to provide a means of enforcing interaction between the vertical stem sections on either side of the void opening. The ties are considered to be fictitious concrete (but weightless) members with rectangular cross sections (HTIE × SLICE). They are assumed not to impede free communication of water through the void.

(k) Tie data must commence with the topmost tie and proceed sequentially downward.

(l) Restrictions on tie data are:

ELTIE(1) ≤ (ELVOID + VOIDHT)

ELTIE(I) ≤ (ELTIE(I - 1) - HTIE(I - 1))

(ELTIE(NTIES) - HTIE(NTIES)) ≥ ELVOID

14. BACKFILL

a. Control--Zero (0) or one (1) line. The entire section may be omitted if backfill effects are not to be considered.

(1) Line contents

LN 'BACkfill' {'side'} {'type'} NUM [SURCH]

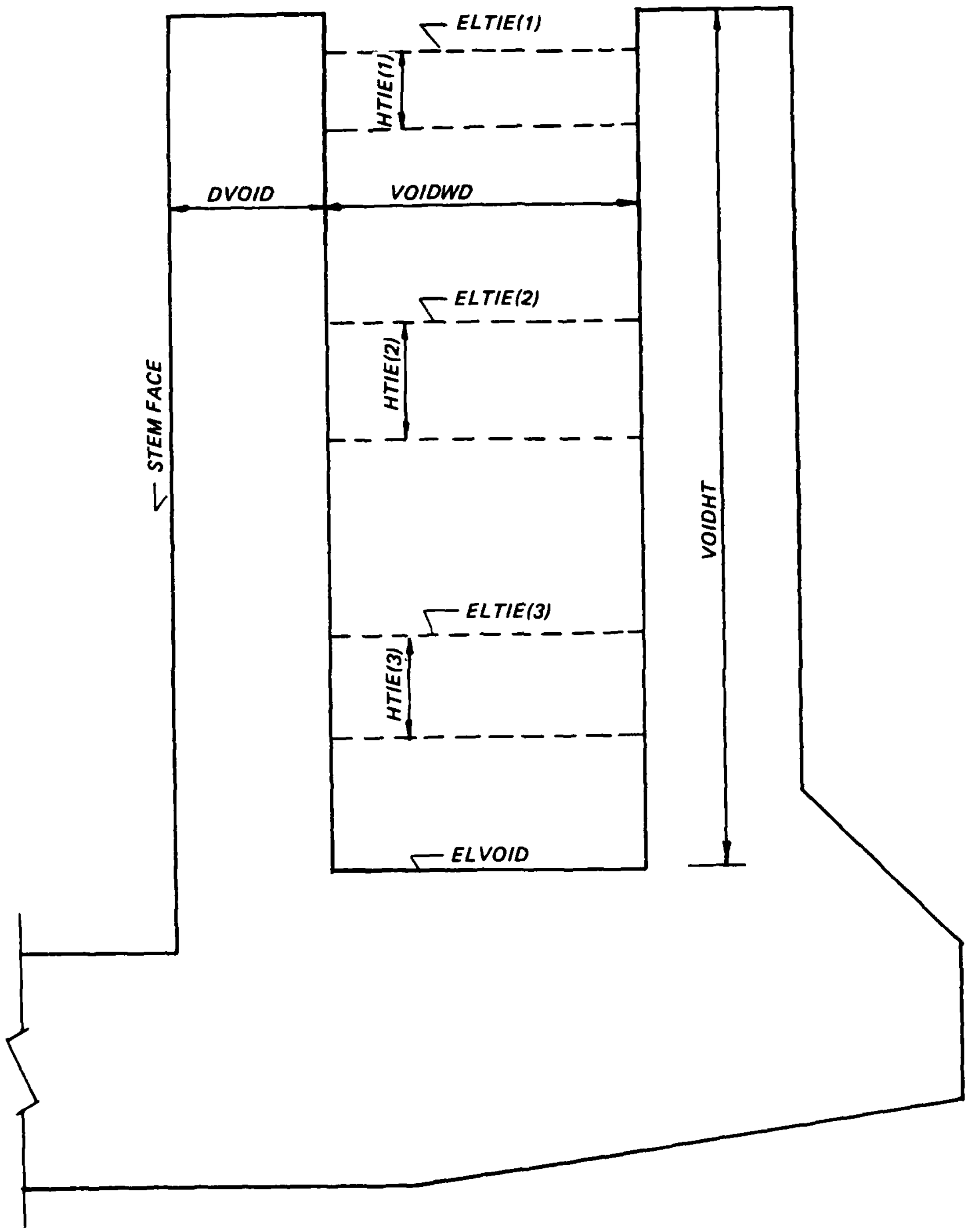


Figure A4. Stem void

(2) Definitions

'BACkfill' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'type'} = 'Soil' or 'Pressure'

NUM = number (1 to 5) of horizontal soil layers if 'type' = 'Soil'

= number (2 to 21) of points on input pressure distribution if 'type' = 'Pressure'

[SURCH] = surface surcharge load (PSF), omit if 'type' = 'Pressure'

b. Backfill soil layer data--Omit if 'type' = 'Pressure'; otherwise one line per layer (NUM lines).

(1) Line contents

LN ELLAY GAMSAT GAMMST SCHT SCHB [SCVT SCVB]

(2) Definitions

ELLAY = elevation (FT) at top of layer

GAMSAT = saturated soil unit weight (PCF)

GAMMST = moist soil unit weight (PCF)

SCHT, SCHB = coefficient for horizontal soil pressure at top and bottom of layer, respectively

[SCVT,SCVB] = coefficient for soil shear stress at top and bottom of layer, respectively. Zero assumed if omitted.

(3) Discussion

(a) See Figure A5 for notation.

(b) Soil layer data lines must commence with the topmost layer (layer 1) and proceed sequentially downward. The last layer input is assumed to continue ad infinitum downward.

Restriction:

$ELLAY(1) \leq ELSTEM(1)$

$ELLAY(1) \geq ELBASE(2)$

$ELLAY(I) < ELLAY(I - 1)$

(c) Horizontal and shear stress soil coefficients are assumed to vary linearly from top to bottom of the layer. Soil coefficients in the last layer input are assumed to be constant throughout the layer equal to the values given for the top of the layer.

(d) If soil lies below ground-water elevation (see section on WATER DATA), effective unit weight is obtained by subtracting the unit weight of water from

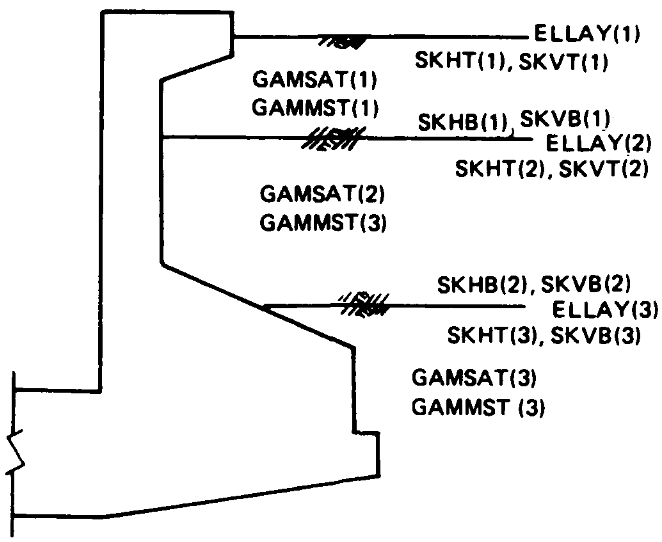


Figure A5. Backfill soil

the saturated soil unit weight. If soil lies above ground-water elevation, the moist soil unit weight is used.

(e) Horizontal soil pressures and soil shear stresses are obtained at the top and bottom of each layer by multiplying the effective vertical soil pressure by the appropriate soil coefficient of that point. A linear variation of pressure and/or shear stress is assumed from top to bottom of each layer. If the ground-water elevation occurs within a layer, an additional layer boundary is automatically inserted at that point.

c. Backfill soil pressure distribution--Omit if 'type' = 'Soil'; otherwise one (1) or more lines

(1) Line contents

LN ELPR(1) EVSPR(1) EHSPR(1) ESSPR(1)

[LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]

(2) Definitions

ELPR(I) = elevation (FT) of i^{th} pressure point

EVSPR(I) = effective vertical soil pressure (PSF) at i^{th} pressure point

EHSPR(I) = effective horizontal soil pressure (PSF) at i^{th} pressure point

ESSPR(I) = effective soil shear stress (PSF) at i^{th} pressure point

(3) Discussion

(a) Four values are required at each point on the backfill soil pressure distribution. Data values are provided in groups of four until NUM points are entered. Points must be provided commencing with the topmost point and proceed sequentially downward.

(b) The restrictions include:

$$\begin{aligned} ELPR(1) &\le ELSTEM(1) \\ ELPR(1) &> ELBASE(2) \\ ELPR(I) &< ELPR(I-1) \\ EVSPR(I) &\ge 0 \\ EHSPR(I) &\ge 0 \\ ESSPR(I) &\ge 0 \end{aligned}$$

d. Discussion of backfill data

(1) If identical backfill conditions exist on both sides of the structure, specify {'side'} = 'Both' and enter data only once. Otherwise, enter data twice: first for 'Rightside' and then for 'Leftside'.

(2) Backfill data are used to determine soil loading on the exterior surface of the stem as follows. Effective stresses, vertical, horizontal, and shear, on horizontal and vertical planes of a soil element at the soil-structure interface are obtained from soil data or from direct input of soil pressures. A Mohr's circle analysis is used to obtain normal and shear (friction) pressures on the external faces of the stem.

(3) Positive effective vertical and horizontal stresses are compression. Positive effective shear stress tends to move the structure downward.

(4) The topmost elevation on the backfill pressure distribution is interpreted as the elevation of the ground surface.

(5) The entire 'BACkfill', data section may be omitted for either or both sides of the structure.

15. BASE REACTION DATA

a. Control--One (1) line

(1) Line contents

LN 'Reaction' {'type'} {'specs'} [{'horizontal option'} {'vertical option'}]

(2) Definitions

'Reaction' = keyword

{'type'} = 'Soil' or 'Pile'

$$\{\text{'specs'}\} = \left\{\begin{array}{l}\text{'Uniform'} \\ \text{'Trapezoidal' PCT} \\ \text{'Rectangular' PCT} \\ \text{'Pressure'}\end{array}\right\}$$, omit if 'type' = 'Pile'

PCT = fraction of uniform base reaction to be applied at chamber centerline (Part IV).

{'horizontal option'} = 'Shear' if unbalanced horizontal loads are to be equilibrated by shear in base. Omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

= 'Friction' if unbalanced horizontal loads are to be equilibrated by friction along structure base; omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

{'vertical option'} = 'Adjust' if unbalanced vertical loads and moments are to be equilibrated by adjusting base pressure distribution; omit if 'type' = 'Pile'; omit unless input file contains sequence of problems

= 'Shear' if unbalanced vertical loads and moments are to be equilibrated by shear in stems; omit if 'type' = 'Pile'; omit unless 'specs' = 'Pressure'; omit unless input file contains sequence of problems

(3) Discussion

(a) Base reaction data must be provided for soil only or piles only. Uplift water forces are entered in the WATER DATA section.

(b) 'Uniform', 'Trapezoidal', and 'Rectangular' soil reaction distributions are evaluated automatically to equilibrate all vertical loads and overturning moments.

(c) 'Pressure' indicates an input pressure distribution is provided.

(d) 'Pile' indicates that pile data are input and no soil reaction is present.

(e) {'horizontal option'} and {'vertical option'} are to be supplied only if the input file contains a sequence of problems. Otherwise, the user will be requested to enter these options by the program during execution. If these items are omitted for any problem in a sequence or are incorrectly specified,

the program will automatically use {'horizontal option'} = 'Friction' and {'vertical option'} = {'Adjust'}.

b. Input base soil pressure distribution--One (1) or more lines. Omit entire section if {'specs'} ≠ 'Pressure'

(1) Line 1 contents

LN {'side'} NPTS DBPR(1) BPR(1) DBPR(2) BPR(2) ...

[LN ... DBPR(NPTS) BPR(NPTS)]

(2) Definitions

{'side'} = 'Rightside', 'Leftside', or 'Both'

NPTS = number (2 to 21) of points on input pressure distribution

DBPR(I) = distance (FT) from chamber centerline to i^{th} pressure point

BPR(I) = base soil pressure (PSF) at i^{th} pressure point

(3) Discussion

(a) The base soil pressure diagram is provided in two parts: once from chamber centerline to extreme rightside of base and once from centerline to extreme leftside of base. If distribution is symmetric about the chamber centerline, specify {'side'} = 'Both' and enter data only once.

(b) Two values (DBPR and BPR) are required for each point on the distribution. Continue pairs of values on additional lines commencing with a line number, until NPTS pairs have been provided.

(c) Pressure point data must commence with the point nearest chamber centerline and proceed sequentially outward.

Restrictions:

DBPR(1) ≥ 0

DBPR(1) > DBPR(I - 1)

BPR(I) ≥ 0

(d) If DBPR(1) > 0, base pressure is assumed to be constant at BPR(1) from the chamber centerline to DBPR(1).

(e) Pressure is assumed to be constant at BRP(NPTS) for all points beyond DBPR(NPTS).

(f) CAUTION: An input base pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for adjustments applied to place entire system in equilibrium.

(g) If base pressure distributions are different on each side, enter data for 'Rightside' first and immediately follow with 'Leftside' data.

c. Pile Data--Omit entire section if 'type' = 'soil'

(1) Control--One (1) line

(a) Line contents

LN 'PILe' 'side'

(b) Definitions

'PILes' = keyword

'side' = 'Rightside', 'Leftside', or 'Both'

(c) Discussion

For pile configurations symmetric about chamber centerline, enter 'side' = 'Both' and provide following subsections only once. For unsymmetric pile configurations, enter entire Pile Data section twice: first for 'Rightside' and then for 'Leftside'.

(2) Pile layout--One (1) to ten (10) lines

(a) Line contents

LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]

(b) Definitions

'Layout' = keyword

NSTART = pile number at start of sequence

DSTART = distance from chamber centerline to intersection of pile centerline with base of structure (FT)

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

[DSTEP] = distance between adjacent piles in the sequence (FT)

(c) Discussion

1. Piles on either side of the chamber centerline are designated by an integer number from 1 to 50. A maximum of fifty (50) piles is permitted on each side of the structure. Pile numbers need not be entered in sequential order. Any pile number in the range 1 to 50 for which layout data are not supplied is ignored.

2. Each line of 'Layout' data describes one sequence of piles to be generated.

3. Pile numbers and distances are generated for each sequence as follows:

Pile No.	Distance from Centerline
NSTART	DSTART
NSTART + NSTEP	DSTART + DSTEP
NSTART + 2* NSTEP	DSTART + 2* DSTEP
.	.
.	.
.	.
NSTOP	DSTART + ((NSTOP - NSTART)/NSTEP)* DSTEP

4. (NSTOP - NSTART)/NSTEP must be an integer.

5. If NSTOP, NSTEP, and DSTEP are all omitted, only one pile is generated.

6. If NSTEP and DSTEP are omitted, NSTEP is assumed to be one and DSTEP is assumed to be zero. This results in piles NSTART, NSTART + 1, NSTART + 2, ..., NSTOP all attached to base of structure at DSTART.

7. If DSTEP is omitted, DSTEP is assumed to be zero. This results in piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP all attached to base of structure at DSTART.

8. Any pile generated beyond the extreme edge(s) of the base is ignored.

9. If any pile is referenced more than once, only the data corresponding to the last reference are used.

10. When 'side' = 'Both', DSTART = 0 may result in two (or more) piles being placed at the chamber centerline. See discussion of batter data below.

11. Every pile referenced in the pile "Layout" data must be assigned either pile/soil data or a pile head stiffness matrix as described below.

(3) Pile/soil properties--Zero (0) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'PROperties' NSTART PE PA PI PL PAXCO DF SS1 SS2 [NSTOP [NSTEP]]

(b) Definitions

'PROproperties' = keyword

NSTART = pile number at start of sequence

PE = pile modulus of elasticity (PSI)

PA = pile cross-sectional area (IN.^{2})

PI = pile moment of inertia (IN.^{4})

PL = pile length (FT)

PAXCO = coefficient for pile axial stiffness

DF = pile head fixity coefficient ($0 \le DF \le 1$); 0 = pinned head, 1 = fixed head

SS1 = constant soil stiffness coefficient (LB/IN.^{2})

SS2 = linear soil stiffness coefficient (LB/IN.^{3})

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.
2. Identical pile properties, pile head fixity, and soil properties are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.
3. (NSTOP - NSTART)/NSTEP must be an integer.
4. If NSTOP and NSTEP are both omitted, only a single pile is generated.
5. If NSTEP is omitted, NSTEP is assumed to be one.
6. If any pile is referenced more than once, only the data for the last reference are used.
7. Soil stiffness is obtained from

$$E_s = SS1 + SS2*Y$$

where E_s is the force per unit length of pile produced by a unit lateral displacement (LB/IN.^{2}), and Y is the distance below the pile head. Soil stiffness coefficients must include effects of pile width, as well as other factors which may influence the soil stiffness.

8. Pile properties, pile head fixity, and soil properties are used to generate pile head stiffness matrices.

(4) Pile head stiffness matrices--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN '<u>STIF</u>fness' NSTART B11 B22 B33 B13 [NSTOP[NSTEP]]

(b) Definitions

'<u>STIF</u>fness' = keyword

NSTART = pile number at start of sequence

B11 = pile lateral stiffness (LB/IN.)

B22 = pile axial stiffness (LB/IN.)

B33 = pile moment stiffness (LB/IN.)

B13 = lateral force-moment coupling stiffness (LB)

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

(c) Discussion

<u>1</u>. Each line of data describes a sequence of piles to be generated.

<u>2</u>. Identical pile head stiffness matrices are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.

<u>3</u>. (NSTOP - NSTART)/NSTEP must be an integer.

<u>4</u>. If NSTOP and NSTEP are both omitted, only a single pile is generated.

<u>5</u>. If NSTEP is omitted, NSTEP is assumed to be one.

<u>6</u>. If any pile is referenced more than once, only the data for the last reference are used.

(5) Pile batter data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN '<u>BAT</u>ter' NSTART BATTER [NSTOP [NSTEP]]

(b) Definitions

'<u>BAT</u>ter' = keyword

NSTART = pile number of first pile in sequence

BATTER = slope of pile vertical (FT) per foot horizontal. Positive if pile slopes downward away from chamber centerline; negative if pile slopes downward toward chamber centerline

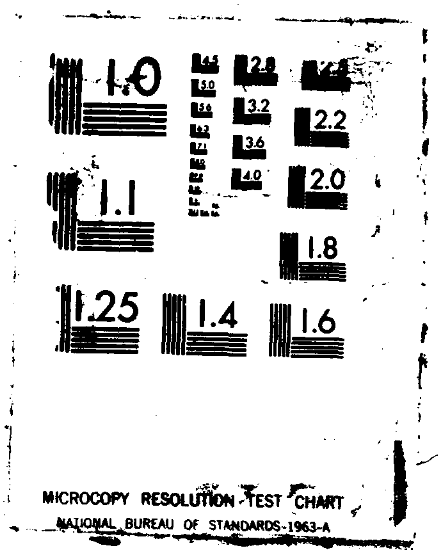
[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile number

AD-A182 553 COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT USER'S GUIDE: COMPUT..(U) DAWKINS (WILLIAM P) STILLWATER OK W P DAWKINS APR 87 WES/TR/ITL-87-1 3/3

UNCLASSIFIED DACW39-83-M-3000 F/G 12/5 NL

END


1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical pile batters are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. All piles are assumed to lie in a vertical plane. BATTER describes the slope of the pile within this vertical plane. When BATTER ≥ 100 or BATTER = 0, the pile is assumed to be exactly vertical. Any pile not assigned a batter is assumed to be exactly vertical.

7. When all pile data are symmetric, vertical piles on the structure centerline are not duplicated in the mirror image established for the 'Leftside'.

(6) Pile load comparison data--Zero (0) or one (1) to ten (10) lines; entire section may be omitted

(a) Line contents

LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM FPM OSFC OFST [NSTOP [NSTEP]]

(b) Definitions

'ALLOWables' = keyword

NSTART = pile number at start of sequence

AC = allowable pile axial compression force (KIPS)

AT = allowable pile axial tension force (KIPS)

ACC = allowable pile axial compression force for combined axial compression and bending (KIPS)

ATT = allowable pile axial tension force for combined axial tension and bending (KIPS)

AM = allowable bending moment (KIP-FT)

FMM = moment magnification factor for amplification effect of axial compression on bending moment

FPM = factor (IN.) for evaluating maximum bending moment in pinned head pile (i.e., DF = 0 or B13, B33 both zero); input value is ignored for piles which transfer moment at pile head

OSFC = load case factor for pile in compression

OSFT = load case factor for pile in tension

[NSTOP] = pile number of last pile in sequence

[NSTEP] = step in pile member

(c) Discussion

1. Each line of data describes a sequence of piles to be generated.

2. Identical "allowable" data values are assigned to all piles NSTART, NSTART + NSTEP, NSTART + 2* NSTEP, ..., NSTOP.

3. (NSTOP - NSTART)/NSTEP must be an integer.

4. If NSTOP and NSTEP are both omitted, only a single pile is generated.

5. If NSTEP is omitted, NSTEP is assumed to be one.

6. If any pile is referenced more than once, only the data for the last reference are used.

7. The following ratios are evaluated and reported:

|FA/OSFC|/AC	for axial compression
|FA/OSFT|/AT	for axial tension
(|FA/ACC| + FMM|BM/AM|)/OSFC	for axial compression
(|FA/ATT| + |BM/AM|)/OSFT	for axial tension

where: FA = calculated pile axial head force

BM = bending moment at pile head for non-pinned head piles

BM = FPM* FV where FV = pile head shear for pinned head piles

8. "ALLOWable" data need to be entered only for piles for which comparisons are desired. No comparisons are performed for any pile not assigned "ALLOWable" data values.

9. Comparisons are made for information purposes only. No action is taken by the program based on the values of the ratios.

10. Values for the load case factors OFSC and OFST should be selected based on the severity and duration expected for a particular loading condition. It may be necessary to alter OFSC and OFST for each loading condition in order to obtain valid comparisons for pile loads.

(7) General discussion of pile data

(a) Pile layout data are used to determine the number of piles present and their identification. Every pile defined by layout data must be assigned pile/soil data or a pile head stiffness matrix; otherwise execution will terminate.

(b) Any pile number assigned pile/soil data or a pile head stiffness matrix but not defined by layout data is ignored.

(c) If different pile conditions exist on each side, enter the entire description for 'Rightside' piles ('Layout', 'PROperties', 'STIFFnesses', 'BATter', and 'ALLOWables') first and immediately follow with 'Leftside' data.

16. WATER DATA

a. Control--Zero (0) or one (1) line. Omit entire section if water effects are not to be considered.

(1) Line contents

LN 'Water' [GAMWAT]

(2) Definitions

'Water' = keyword

[GAMWAT] = unit weight of water (PCF). Assumed to be 62.4 PCF if omitted

b. External water--Zero (0), one (1), or two (2) or more lines. Entire section may be omitted.

(1) Control--One (1) line--Line contents

LN 'External' {'side'} {'type'} [ELGW [ELSURW]]

(2) Definitions

'External' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'type'} = 'Elevation' if external water effects are to be calculated from input water elevations

= 'Pressure' if water pressure distribution provided

[ELGW] = elevation (FT) of ground-water surface; omit if {'type'} = 'Pressure'

[ELSURW] = elevation (FT) of surcharge water surface; omit if surcharge water is not to be considered; omit if {'type'} = 'Pressure'

(3) Discussion for {'type'} = 'Elevation'

(a) Ground water affects backfill soil loads by altering effective soil unit weight as well as producing horizontal hydrostatic pressures on the lateral surface of the structure.

(b) Surcharge water is assumed to lie above the ground surface and to be isolated from ground water. Surcharge water produces hydrostatic pressures on the lateral surface of the structure. Vertical pressure of surcharge water on ground surface is added to effective vertical soil pressures when soil layer data are provided in the backfill description.

Restrictions:

ELSURW ≤ ELSTEM(1)

ELSURW > ELLAY(1) if backfill soil data provided

ELSURW > ELPR(1) if backfill pressure distribution provided

(4) Data lines if {'type'} = 'Pressure'

(a) Line 1 contents

LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2) ...

[LN ... ELWPRE(NPTS) WPRE(NPTS)]

(b) Definitions

NPTS = number (2 to 21) of points on pressure distribution provided

ELWPRE(I) = elevation (FT) at i^{th} pressure point

WPRE(I) = pressure (PSF) at i^{th} pressure point

(c) Discussion

1. Elevation and pressure data are provided in pairs. Data pairs may be continued on additional lines following a line number until NPTS pairs have been provided.

2. Input water pressures act normal to the exterior surfaces of the structure between ELWPRE(1) and ELBASE(2). No other water effect is implied or used.

3. Restrictions:

ELWPRE(1) ≤ ELSTEM(1)

ELWPRE(I) < ELWPRE(I - 1)

ELWPRE(I) ≥ ELBASE(2)

4. Input water pressure distribution produces only loads normal to the lateral surfaces of structure. No other effect is implied or used.

(5) Discussion of external water data

(a) See Figure A6 for notation

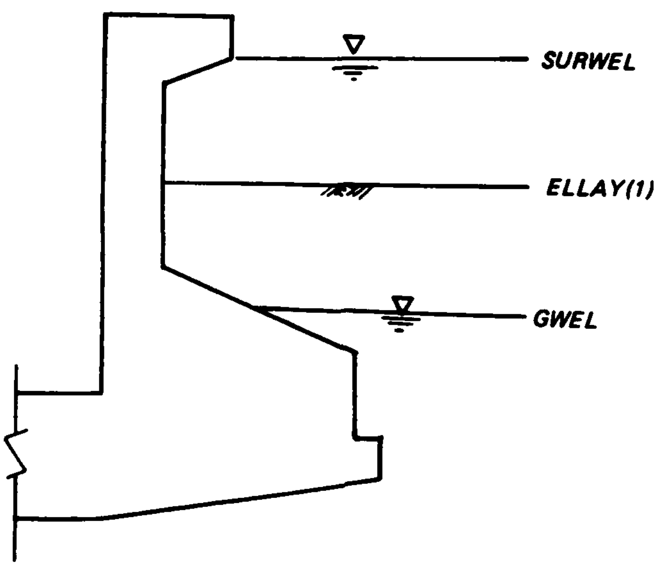


Figure A6. External water

(b) If identical external water effects exist on both sides of the structure, enter {'side'} = 'Both' and enter data only once. If different effects exist on the two sides, enter data twice: first for 'Rightside' and then for 'Leftside'.

c. Uplift water effects on base--Zero (0) or one (1) or more lines. Entire section may be omitted

(1) Control--One (1) line

(a) Line contents

LN 'Uplift' {'type'} [UPRITE [UPLEFT]]

(b) Definitions

'Uplift' = keyword

{'type'} = 'Elevation' if uplift pressures are to be calculated from input water elevations

= 'Pressure' if uplift pressure distribution is provided

[UPRITE] = effective uplift water elevation at extreme rightside of base (FT); omit if {'type'} = 'Pressure'

[UPLEFT] = effective uplift water elevation at extreme leftside of base (FT); assumed to be equal to UPRITE if omitted; omit if {'type'} = 'Pressure'

(c) Discussion for {'type'} = 'Elevation'

1. Uplift pressures on the base are obtained by multiplying the weight of water by the input heads at the extremes of the base.

2. Uplift pressure is assumed to vary linearly between the extremes.

3. Restrictions:

   UPRITE ≥ ELBASE(2) on rightside

   UPLEFT ≥ ELBASE(2) on leftside

4. A straight line between UPRITE and UPLEFT must not intersect the base of the structure at any point.

(2) Input base uplift pressure distribution--One (1) or more lines. Omit entire section if {'type'} = 'Elevation'

(a) Line 1 contents

LN {'side'} NPTS DUPR(1) UPR(1) DUPR(2) UPR(2) ...

[LN... DUPR(NPTS) UPR(NPTS)]

(b) Definitions

{'side'} = 'Rightside', 'Leftside', or 'Both'

NPTS = number (1 to 21) of points on input pressure distribution

DUPR(I) = distance (FT) from chamber centerline to i^{th} pressure point

UPR(I) = uplift pressure (PSF) at i^{th} pressure point

(c) Discussion

1. The base uplift pressure diagram is provided in two parts: first from chamber centerline to extreme rightside of base; then from chamber centerline to extreme leftside of base. If the distribution is symmetric about the centerline, specify {'side'} = 'Both' and enter data only once.

2. Two values (DUPR and UPR) are required for each point on the distribution. Continue pairs of values on additional lines, commencing with a line number, until NPTS pairs have been provided.

3. Pressure point data must commence with the point nearest the chamber centerline and proceed sequentially outward.

Restrictions:

DUPR(1) ≥ 0

DUPR(I) > DUPR (I - 1)

UPR(I) ≥ 0

4. If DUPR(I) > 0, uplift pressure is assumed to be constant at UPR(1) from the chamber centerline to DUPR(1).

5. Uplift pressure is assumed to be constant at UPR(NPTS) for all points beyond DUPR(NPTS).

6. CAUTION: An input uplift pressure diagram may not equilibrate all vertical loads and overturning moments. See Part IV for reaction adjustments applied to place entire system in equilibrium.

d. Internal water--Zero (0) or one (1) line. Entire section may be omitted.

(1) Line contents

LN 'Internal' ELCHMW [[ELCWR] [ELCWL]]

(2) Definitions

'Internal' = keyword

ELCHMW = water elevation in chamber (FT)

[ELCWR] = effective water elevation in rightside culvert (and stem void) (FT); omit if culvert is not present

[ELCWL] = effective water elevation in leftside culvert (and stem void) (FT); omit if culvert is not present

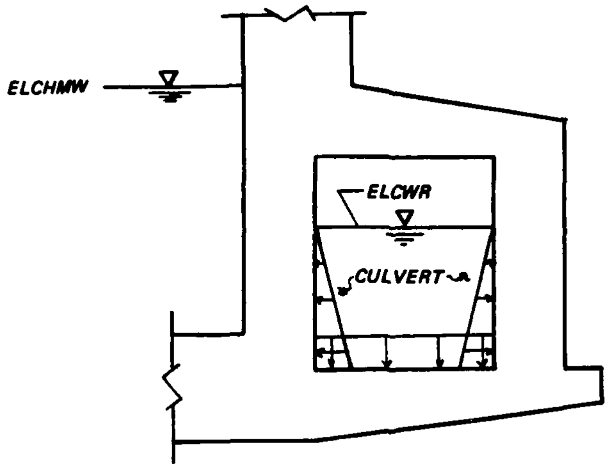
(3) Discussion

(a) See Figure A7 for notation

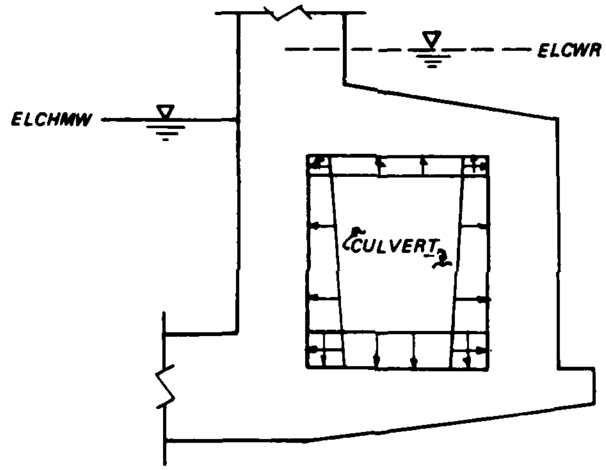
(b) If ELCHMW is less than ELFLOR, the chamber is assumed to be dry. ELCHMW must be less than or equal to ELSTEM(1).

(c) If effective water elevation in the culvert(s) is less than ELCUL (rightside or leftside), the culvert is assumed to be dry.

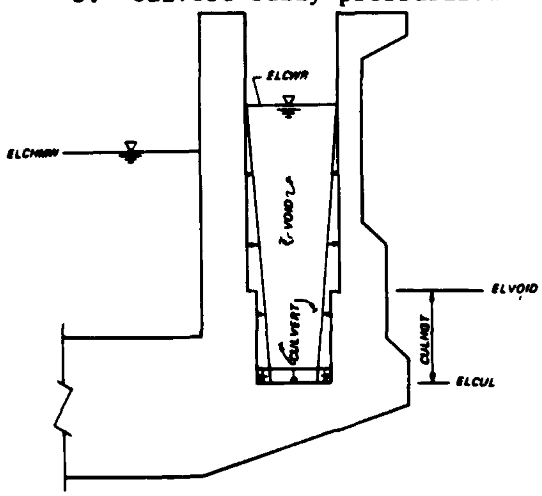
(d) If the culvert top is closed, i.e., ELVOID ≥ (ELCUL + CULHGT), and the effective water elevation in the culvert is above the top of the culvert, the culvert is assumed to be pressurized. In this case the stem void (if present) is assumed to be dry.



a. Culvert partially filled



b. Culvert fully pressurized



c. Void and culvert connected

Figure A7. Internal water

(e) If the culvert is open to the stem void, i.e., ELVOID = (ELCUL + CULHGT), then the interior walls of the culvert (and void) are subjected only to triangular hydrostatic pressures.

(f) Culvert water elevation may result in hydrostatic pressures on all interior surfaces of a closed culvert. If the culvert is open to the stem void and the stem void is closed at the top, i.e., (ELVOID + VOIDHT) < ELSTEM(1), culvert water elevation may result in hydrostatic pressures on all interior surfaces of the culvert and void.

17. ADDITIONAL LOAD DATA--Zero (0) or two (2) or more lines. Entire section may be omitted.

a. Control--One (1) or more lines; line sequences may be repeated as necessary

(1) Line contents

LN 'Loads' {'side'} {'location'}

(2) Definitions

'Loads' = keyword

{'side'} = 'Rightside', 'Leftside', or 'Both'

{'location'} = 'Stem Exterior' if loads act on exterior face of stem

= 'Stem Interior' if loads act on interior face of stem

= 'Stem Top' if loads act on top horizontal surface of stem

= 'Floor' if loads act on chamber floor

= 'Base' if loads act on base of structure

b. Data lines for loads acting on stem faces

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1) ...

[LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated loads

ELCSLD(I) = elevation at which load acts (FT)

HCSLD(I) = magnitude of horizontal load component (PLF)

VCSLD(I) = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line 1 contents

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VDSLD(1) ...

[LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

ELDSLD(I) = elevation at load point (FT)

HDSLD(I) = magnitude of horizontal load at i^{th} load point (PSF)

VDSLD(I) = magnitude of vertical load at i^{th} load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward the centerline of the chamber.

(b) All vertical loads are positive if they act downward.

(c) For concentrated loads on exterior face of stem:

ELBASE(2) ≤ ELCSLD ≤ ELSTEM(1)

(d) For concentrated loads on interior face of stem:

ELFLOR ≤ ELCSLD ≤ ELSTEM(1)

(e) Concentrated loads are interpreted as line loads acting on the slice.

(f) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided.

(g) Distributed loads on the exterior face of the stem must begin at or below the top of the stem and terminate at or above the juncture of the base and stem, i.e.,

ELDSLD(1) ≤ ELSTEM(1)

ELDSLD(I) ≤ ELDSLD(I - 1)

ELDSLD(NPTS) ≥ ELBASE(2)

(h) Distributed loads on the interior face of the stem must begin at or below the top of the stem and

terminate at or above the chamber floor, i.e.,

ELDSLD(1) ≤ ELSTEM(1)

ELDSLD(I) ≤ ELDSLD(I - 1)

ELDSLD(NPTS) ≥ ELFLOR(2)

(i) Distributed loads are assumed to vary linearly between input points.

(j) If two load points are specified at the same elevation, the first is assumed to exist immediately above the elevation and the second immediately below the elevation.

(k) Distributed loads are interpreted as force per foot of slice per foot of vertical projection of the stem surface.

c. Data lines for loads acting on top horizontal surface of stem

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS DCSTLD(1) HCSTLD(1) VCSTLD(2) ...

[LN ... DCSTLD(NLDS) HCSTLD(NLDS) VCSTLD(NLDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 or 10) of concentrated loads

DCSTLD = distance from inside stem face at which load acts (FT)

HCSTLD = magnitude of horizontal load component (PLF)

VCSTLD = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line contents

LN 'Distributed' NPTS DDSTLD(I) HDSTLD(I) VDSTLD(I) ...

[LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

DDSTLD(I) = distance from inside stem face to i^{th} load point (FT)

HDSTLD(I) = magnitude of horizontal load at i^{th} load point (PLF)

VDSTLD(I) = magnitude of vertical load at i^{th} load point (PLF)

(c) Discussion

1. All horizontal loads are positive if they act toward the chamber centerline.

2. All vertical loads are positive if they act downward.

3. For loads on the stem top:

   0. ≤ DCSTLD(I) ≤ DSTEM(1)

   0. ≤ DDSTLD(1)

   DDSTLD(I) ≥ DDSTLD(I - 1)

   DDSTLD(PTS) ≤ DSTEM(1)

4. If the top of a stem void is open at the top of the stem, loads may not be applied inside of the void opening.

5. Distributed loads are assumed to vary linearly between input points. If two points are input at the same distance from the stem face, the first is assumed to exist on the chamber side of the point and the second is assumed to exist immediately outside the point.

d. Data lines for loads acting on chamber floor and structure base

(1) Concentrated loads--One (1) or more lines

(a) Line contents

LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...

[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NCDS)]

(b) Definitions

'Concentrated' = keyword

NLDS = number (1 to 10) of concentrated loads

DCFBLD = distance from chamber centerline at which load acts (FT)

HCFBLD = magnitude of horizontal load component (PLF)

VCFBLD = magnitude of vertical load component (PLF)

(2) Distributed loads--One (1) or more lines

(a) Line 1 contents

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1)

[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

(b) Definitions

'Distributed' = keyword

NPTS = number (2 to 21) of load point values to be provided

DDFBLD(I) = distance from chamber centerline to i^{th} load point (FT)

HDFBLD(I) = magnitude of horizontal load at i^{th} load point (PSF)

VDFBLD(I) = magnitude of vertical load at i^{th} load point (PSF)

(3) Discussion

(a) All horizontal loads are positive if they act toward the chamber centerline.

(b) All vertical loads are positive if they act downward.

(c) For concentrated loads on the chamber floor

0. ≤ DCFBLD(I) ≤ FLRWID

(d) For concentrated loads on the structure base

0. ≤ DCFBLD(I) ≤ DBASE(2)

(e) Concentrated loads are interpreted as line loads acting on the slice.

(f) Three values are required for each point on a distributed load distribution. Continue groups of three on additional lines commencing with a line number until NPTS groups have been provided. Distributed load point data must commence with the point nearest the chamber centerline and proceed sequentially outward.

(g) For distributed loads on chamber floor

0. ≤ DDFBLD(1)

DDFBLD(I) ≥ DDFBLD(I - 1)

DDFBLD(NPTS) ≤ FLRWID

(h) For distributed loads on structure base

0. ≤ DDFBLD(1)

DDFBLD(I) > DDFBLD(I - 1)

DDFBLD(NPTS) ≤ DBASE(2)

(i) Distributed loads are assumed to vary linearly between input points. If two points are input at the same distance from the chamber centerline, the first is assumed to exist immediately inside the point and the second is assumed to exist immediately outside the point.

(j) Distributed loads on the base are interpreted as force per foot of slice per foot of horizontal projection of the base.

18. LIST OF MEMBERS FOR DETAILED MEMBER FORCE OUTPUT--Zero (0), one (1), or two (2) lines. Omit unless input file contains sequence of problems; omit if 'mode' = 'Equilibrium'.

a. Line contents

[LN 'Output Members' {'side'} {list}]

b. Definitions

'Output Members' = keywords

{'side'} = 'Rightside', 'Leftside', or 'Both'

{list} = list of member numbers for which detailed member forces are desired

= 'All' if detailed forces for all members are desired

= list of individual member numbers of form N1 N2 ... N4 TO N5 ...

c. Discussion

(1) When data are entered from the terminal or from a file containing only one problem, the user is requested to provide this information during program execution.

(2) If this section is omitted, no detailed member forces are output during a sequence of solutions.

(3) For symmetric systems, enter data for 'Rightside' only.

(4) For unsymmetric systems, if different lists of member numbers are desired for the two sides, enter data for 'Rightside' first and immediately follow with data for 'Leftside'.

19. TERMINATION--One (1) line

a. Line contents

LN 'Finish' ['Rerun']

b. Definitions

'Finish' = keyword to indicate end of problem data set

['Rerun'] = keyword to indicate additional problem data set follows for sequence of problems. Omit unless input file contains sequence of problems. Omit on last line of sequence.

Abbreviated Input Guide

20. CONTROL

a. Heading--One (1) to four (4) lines

LN 'heading'

[LN 'heading']

[LN 'heading']

[LN 'heading']

b. Method--One (1) line

LN 'Method' $\begin{Bmatrix}\text{'Equilibrium'}\\ \text{'Frame' RLF}\end{Bmatrix}$

21. STRUCTURE

a. Control--One (1) line

LN 'Structure' EC PR WTCONC [SLICE]

b. Floor--One (1) line

LN 'Floor' FLRWID ELFLOR [FLRFIL]

c. Base--One (1) or two (2) lines

LN 'Base' {'side'} DBASE(1) ELBASE(1) [DBASE(2) ELBASE(2)]

d. Stem--One (1) to four (4) lines

LN 'Stem' {'side'} NPTS DSTEM(1) ELSTEM(1) ...

[LN ... DSTEM(NPTS) ELSTEM(NPTS)]

e. Culvert--Zero (0) to two (2) lines

[LN 'Culvert' {'side'} CDUL CULWID ELCUL CULHGT [CULFIL]]

f. Void--Zero (0) to four (4) lines

LN 'Void' {'side'} DVOID VOIDWD ELVOID VOIDHT [NTIES]]

[LN ELTIE(1) HTIE(1) ... ELTIE(NTIES) HTIE(NTIES)]

22. BACKFILL

a. Soil data--Omit if pressure distribution input

(1) Control--One (1) line

```
LN 'BACkfill' {'side'} 'Soil' NUM [SURCH]
```

(2) Layer data--One (1) to five (5) lines

```
LN ELLAY GAMSAT GAMMST SCHT SCHB [SCVT SCVB]
```

b. Pressure data--Omit if soil data input

(1) Control--One (1) line

```
LN 'BACkfill' {'side'} 'Pressure' NUM
```

(2) Data lines

```
LN ELPR(1) EVSPR(1) EHSPR(1) ESSPR(1) ...
[LN ... ELPR(NUM) EVSPR(NUM) EHSPR(NUM) ESSPR(NUM)]
```

23. BASE REACTION

a. Soil reaction--One (1) to three (3) lines

```
                        ('Uniform'          )   [ ( 'Shear'    ) ( 'Adjust' ) ]
LN  'Reaction'  'Soil' < 'Trapezoidal' PCT   >  [ <             > <          > ]
                        ( 'Rectangular' PCT )   [ ( 'Friction' ) ( 'Shear'  ) ]
                        ('Pressure'         )
```

Additional lines for 'Pressure'

```
LN {'side'} NPTS DBPR(1) BPR(1) DBPR(2) BPR(2) ...
[LN ... DBPR(NPTS) BPR(NPTS)]
```

b. Pile reaction

(1) Control--Two (2) lines

```
LN 'Reaction' 'Pile'
LN 'Pile' {'side'}
```

(2) Pile layout--One (1) or more lines

```
LN 'Layout' NSTART DSTART [NSTOP [NSTEP [DSTEP]]]
```

(3) Pile properties--Zero (0) or one (1) to ten (10) lines; required if pile head stiffness matrices are calculated by program

```
LN 'PROperties' NSTART PE PD PA PI PL PAXCO DE SS1
SS2 [NSTOP [NSTEP]]
```

(4) Pile stiffness matrices--Zero (0) to ten (10) lines

```
LN 'STIFfness' NSTART B11 B22 B33 B13 [NSTOP [NSTEP]]
```

(5) Pile batter--Zero (0) to ten (10) lines

```
LN 'BATter' NSTART BATTER [NSTOP [NSTEP]]
```

(6) Pile load comparison--Zero (0) to ten (10) lines

```
LN 'ALLOWables' NSTART AC AT ACC ATT AM FMM
FPM OFSC OFST [NSTOP [NSTEP]]
```

24. WATER

a. Control--Zero (0) or one (1) line

LN 'Water' [GAMWAT]

b. External water--Zero (0) or one (1) or more lines

(1) Water elevations input--One (1) line

LN 'External' {'side'} 'Elevation' ELGW [ELSURW]

(2) Water pressure distribution input--Two (2) or more lines

(a) Control--One (1) line

LN 'External' {'side'} 'Pressure'

(b) Data lines--One (1) or more lines

LN NPTS ELWPRE(1) WPRE(1) ELWPRE(2) WPRE(2)

[LN ... ELWPR(NPTS) WPRE(NPTS)]

c. Uplift water--Zero (0) or one (1) or more lines

(1) Uplift water elevations input--One (1) line

LN 'Uplift' 'Elevation' UPRITE [UPLEFT]

(2) Uplift pressure distribution input--Two (2) or more lines

(a) Control--One (1) line

LN 'Uplift' 'Pressure'

(b) Data lines--One (1) or more lines

LN {'side'} NPTS DUPR(1) UPR(1) DUPR(2) UPR(2) ...

[LN ... DUPR(NPTS) UPR(NPTS)]

d. Internal water--Zero (0) or one (1) line

LN 'Internal' ELCHMW [ELCWR [ELCWL]]

25. ADDITIONAL LOADS

a. Loads on stem faces--Zero (0) or two (2) or more lines

(1) Control--One (1) line

LN 'Loads' {'side'} $\left\{ \begin{array}{l} \text{'Stem Exterior'} \\ \text{'Stem Interior'} \end{array} \right\}$

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS ELCSLD(1) HCSLD(1) VCSLD(1)...

[LN ... ELCSLD(NLDS) HCSLD(NLDS) VCSLD(NCDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS ELDSLD(1) HDSLD(1) VCSLD(1) ...

[LN ... ELDSLD(NPTS) HDSLD(NPTS) VDSLD(NPTS)]

b. Loads on stem top--Zero (0) or two (2) or more lines

(1) Control--One (1) line

LN 'Loads' {'side'} {'Stem Top'}

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCSTLD(1) HDSTLD(1) VDSTLD(1) ...

[LN ... DCSTLD(NLDS) HDSTLD(NLDS) VDSTLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDSTLD(1) HDSTLD(1) VDSTLD(1) ...

[LN ... DDSTLD(NPTS) HDSTLD(NPTS) VDSTLD(NPTS)]

c. Loads on chamber floor or structure base--Zero (0) or two (2) or more lines

(1) Control--One (1) line

LN 'Loads' {'side'} $\left\{\begin{array}{l}\text{'Floor'}\\\text{'Base'}\end{array}\right\}$

(2) Data lines for concentrated loads--Zero (0) or one (1) or more lines

LN 'Concentrated' NLDS DCFBLD(1) HCFBLD(1) VCFBLD(1) ...

[LN ... DCFBLD(NLDS) HCFBLD(NLDS) VCFBLD(NLDS)]

(3) Data lines for distributed loads--Zero (0) or one (1) or more lines

LN 'Distributed' NPTS DDFBLD(1) HDFBLD(1) VDFBLD(1) ...

[LN ... DDFBLD(NPTS) HDFBLD(NPTS) VDFBLD(NPTS)]

26. DETAILED MEMBER FORCE LIST--Zero (0), one (1), or two (2) lines

LN 'Output Members' {'side'} $\left\{\begin{array}{l}\text{'All'}\\\text{list}\end{array}\right\}$

27. TERMINATION--One (1) line

LN 'Finish' ['Rerun']

APPENDIX B: GTSTRUDL SOLUTIONS

STRUDL Model

1. Joints in the STRUDL model were assigned at the locations of the joints in the CUFRAM model. Additional STRUDL joints were located at the ends of the flexible lengths of the CUFRAM members at the intersection of any piles with the structure base and at the base of STRUDL members simulating the piles.

2. STRUDL members corresponding to prismatic flexible CUFRAM members were assigned cross-sectional areas and moments of inertia calculated from the dimensions of the structure. Because STRUDL does not have the direct capability of evaluating the stiffness matrix for a tapered member, the stiffness matrices for tapered members were obtained by the process used in CUFRAM and provided to STRUDL. All STRUDL members representing rigid links in the CUFRAM model were assigned area and inertia properties several times larger than those of the largest prismatic member. Pile head stiffnesses were evaluated separately and supplied to STRUDL as member stiffness matrices.

3. Loads were applied to the STRUDL model as follows. Uniform loads on prismatic members were applied as member loads. Nonuniform loads on prismatic members and loads acting on tapered members were converted by the processes employed in CUFRAM to fixed end forces which were applied to the STRUDL model as equivalent joint loads.

Interpretation of Results

4. With due regard to the sign conventions employed by the two programs, joint displacements, pile head forces, and member end forces for prismatic members with uniform loads may be compared directly. For members with nonuniform loads and for tapered members, fixed end forces must be added to the member end forces reported by STRUDL for comparison with CUFRAM results. Figures B1, B2, and B3 show the GTSTRUDL solutions for CUFRAM Examples 1, 2B, and 3.

```
STRUDL 'CUEX1' 'GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$ CUFRAM MODEL JOINTS
1 0        38        S
2 46.85482 38.46681
3 68       40.5
4 44.5     85
5 45.89617 99.30601
$ JOINTS AT ENDS OF FLEXIBLE LENGTHS
21 43.21371 38
23 50.71371 38.83786
24 47.08435 42.61670
54 44.5     96.07650
MEMBER INCIDENCES
$ CUFRAM MODEL MEMBERS
1 1  21
2 23 3
3 24 4
4 4  54
$ RIGID LINKS
12 21 2
23 2  23
24 2  24
45 54 5
MEMBER PROPERTIES
1 PRISMATIC AX 12 AY 10       IZ 144
4 PRISMATIC AX 5  AY  4.16667 IZ 10.41667
2 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 2.99107E8  0           0
ROW 2 0          2.97866E7 -2.12036E8
ROW 6 0         -2.12036E8  2.71740E9
3 STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.41039E8  0           0
ROW 2 0          2.04180E6 -2.88996E7
ROW 6 0         -2.88996E7  6.91650E8
$ RIGID LINKS
12 23 24 45 PRISMATIC AX 5000 IZ 7.0E4
CONSTANTS E 4.32E8
CONSTANTS G 1.80E8
LOADING 1
$ MEMBER UNIFORM LOADS
MEMBER 1 LOADS FORCE Y UNIFORM W 718.96431 LA 0 LB 42
JOINT LOADS
$ FORCES ON RIGID BLOCKS
2 FORCE X -7.24510E3 Y  3.99060E4 MOMENT Z -3.27413E4
5 FORCE               Y -9.15000E3
$ EQUIVALENT JOINT LOADS FOR NONUNIFORM MEMBER LOADS AND HEEL END
23 FORCE X -5.36059E3 Y  2.82199E3 MOMENT Z  3.84311E3
 3 FORCE X -2.67843E4 Y -2.03241E3 MOMENT Z  4.38534E3
24 FORCE X  1.60821E4 Y -3.06778E4 MOMENT Z -1.36362E5
 4 FORCE X  2.48555E4 Y -2.76787E4 MOMENT Z  1.53179E5
54 FORCE X  8.13637E2 Y -3.38555E3 MOMENT Z  2.15505E3
```

Figure B1. GTSTRUDL solution for CUFRAM Example 1--type 1 monolith (Continued)

```
 LOADING LIST ALL
 STIFFNESS ANALYSIS
$ CUFRAM MODEL JOINTS
 LIST DISPLACEMENTS JOINTS 2 3 4 5

   ****************************
   *RESULTS OF LATEST ANALYSES*
   ****************************

    PROBLEM - CUEX1     TITLE - GTSTRUDL SOLUTION FOR TYPE 1 MONOLITH
    ACTIVE UNITS  FEET LB   RAD  DEGF SEC

JOINT                 X DISP.         Y DISP.         Z ROT.

2                     .0005850       -.0326286       -.0012112
3                     .0029568       -.0582332       -.0012116
4                     .0780203       -.0287878       -.0018994
5                     .1055526       -.0315560       -.0019367

$ CUFRAM MODEL MEMBERS
 LIST FORCES MEMBERS 1 2 3 4

MEMBER   JOINT           AXIAL           SHEAR Y           BENDING Z

1        1         -2361.2525702         -.0215749   1967114.6154055
1        21         2361.2525702    -30196.4794451  -1296339.2310624
2        23        26855.8610118      -540.5055160     -5001.0877435
2        3        -26855.8610118       540.5055160     -4385.3400002
3        24        41701.9931512    -23174.0112030   -850468.5272026
3        4         -41701.9931512     23174.0112030   -133546.7566838
4        4          12535.5527747       813.6429889     19632.2433158
4        54        -12535.5527747      -813.6429889    -10619.9267494
 FINISH
```

Figure B1. (Concluded)

```
STRUDL 'EX2B' 'GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH'

TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$
$  RIGHTSIDE CUFRAM MODEL JOINTS
$
 1     0         19
'R2'  10         19
'R3'  20         19
'R4'  30         19
'R5'  40         19
'R6'  46         19                 $ RIGID BLOCK 2
'R7'  55         18
'R8'  60         18
'R9'  64         18                 $ RIGID BLOCK 1
'R10' 63.94286 35.19286             $ RIGID BLOCK 4
'R11' 46         36.5               $ RIGID BLOCK 3
'R12' 44         55.5
'R13' 46.29543 70.55508             $ RIGID BLOCK 6
$
$ RIGHTSIDE JOINTS AT ENDS OF FLEXIBLE LENGTHS
$
'R65'    42 19
'R67'    50 18
'R98'    62 18
'R910'   64 21
'R109'   64 33
'R1011'  62 35.375
'R611'   46 23
'R116'   46 33
'R1110'  50 36.5
'R1112'  46 40
'R1312'  44 65.5
$
$ RIGHTSIDE JOINTS ON BASE AT PILE HEADS
$
'BP19'    0  15
'RBP2'    10 15
'RBP310'  20 15
'RBP4'    30 15
'RBP511'  40 15
'RBP12'   45 15
'RBP613'  50 15
'RBP714'  55 15
'RBP8'    60 15
$
$ RIGHTSIDE JOINTS AT BOTTOM OF PILES (FICTITIOUS)
$
$ VERTICAL PILES
'PB19'    0  10 S
'RPB2'    10 10 S
'RPB310'  20 10 S
'RPB4'    30 10 S
```

Figure B2. GTSTRUDL solution for CUFRAM Example 2B--type 2 monolith with pile supports (Sheet 1 of 9)

```
'RPB5'   40 10 S
'RPB6'   50 10 S
'RPB7'   55 10 S
'RPB8'   60 10 S
$ BATTERED PILES
'RPB11'  41 12 S
'RPB12'  46 12 S
'RPB13'  51 12 S
'RPB14'  56 12 S
$
$ LEFTSIDE CUFRAM MODEL JOINTS
$
'L2'  -10       19
'L3'  -20       19
'L4'  -30       19
'L5'  -40       19
'L6'  -46       19               $ RIGID BLOCK 2
'L7'  -55       18
'L8'  -60       18
'L9'  -64       18               $ RIGID BLOCK 1
'L10' -63.94286 35.19286         $ RIGID BLOCK 4
'L11' -46       36.5             $ RIGID BLOCK 3
'L12' -44       55.5
'L13' -46.29543 75.55508         $ RIGID BLOCK 6
$
$ LEFTSIDE JOINTS AT ENDS OF FLEXIBLE LENGTHS
$
'L65'   -42 19
'L67'   -50 18
'L98'   -62 18
'L910'  -64 21
'L109'  -64 33
'L1011' -62 35.375
'L611'  -46 23
'L116'  -46 33
'L1110' -50 36.5
'L1112' -46 40
'L1312' -44 65.5
$
$ LEFTSIDE JOINTS ON BASE AT PILE HEADS
$
'LBP2'   -10 15
'LBP310' -20 15
'LBP4'   -30 15
'LBP511' -40 15
'LBP12'  -45 15
'LBP613' -50 15
'LBP714' -55 15
'LBP8'   -60 15
$
$ LEFTSIDE JOINTS AT BOTTOMS OF PILES (FICTITIOUS)
$
$ VERTICAL PILES
'LPB2'   -10 10 S
'LPB310' -20 10 S
'LPB4'   -30 10 S
'LPB5'   -40 10 S
```

Figure B2. (Sheet 2 of 9)

```
'LPB6'    -50 10 S
'LPB7'    -55 10 S
'LPB8'    -60 10 S
$ BATTERED PILES
'LPB11'   -41 12 S
'LPB12'   -46 12 S
'LPB13'   -51 12 S
'LPB14'   -56 12 S
$
MEMBER INCIDENCES
$
$ RIGHTSIDE CUFRAM MODEL MEMBERS
'R1'     1       'R2'
'R2'    'R2'     'R3'
'R3'    'R3'     'R4'
'R4'    'R4'     'R5'
'R5'    'R5'     'R65'
'R6'    'R67'    'R7'
'R7'    'R7'     'R8'
'R8'    'R8'     'R98'
'R9'    'R910'   'R109'
'R10'   'R611'   'R116'
'R11'   'R1110'  'R1011'
'R12'   'R1112'  'R12'
'R13'   'R12'    'R1312'
$ RIGHTSIDE RIGID LINKS AT RIGID BLOCKS
'RL56'    'R65'    'R6'
'RL67'    'R6'     'R67'
'RL89'    'R98'    'R9'
'RL910'   'R9'     'R910'
'RL109'   'R109'   'R10'
'RL611'   'R6'     'R611'
'RL116'   'R116'   'R11'
'RL1110'  'R11'    'R1110'
'RL1011'  'R1011'  'R10'
'RL1112'  'R11'    'R1112'
'RL1213'  'R1312'  'R13'
$ RIGHTSIDE RIGID LINKS AT PILE HEADS
'LP19'     1    'BP19'
'RLP2'    'R2'  'RBP2'
'RLP310'  'R3'  'RBP310'
'RLP4'    'R4'  'RBP4'
'RLP511'  'R5'  'RBP511'
'RLP12'   'R6'  'RBP12'
'RLP613'  'R6'  'RBP613'
'RLP714'  'R7'  'RBP714'
'RLP8'    'R8'  'RBP8'
$
$ RIGHTSIDE PILES (FICTITIOUS)
$
$ VERTICAL PILES
'P1'    'BP19'    'BP19'
'RP2'   'RPB2'    'RBP2'
'RP3'   'RPB310'  'RBP310'
'RP4'   'RPB4'    'RBP4'
'RP5'   'RPB5'    'RBP511'
'RP6'   'RPB6'    'RBP613'
```

Figure B2. (Sheet 3 of 9)

```
'RP7'  'RPB7'   'RBP714'
'RP8'  'RPB8'   'RBP8'
'P9'   'PB19'   'BP19'
'RP10' 'RPB310' 'RBP310'
$ BATTERED PILES
'RP11' 'RPB11' 'RBP511'
'RP12' 'RPB12' 'RBP12'
'RP13' 'RPB13' 'RBP613'
'RP14' 'RPB14' 'RBP714'
$
$ LEFTSIDE CUFRAM MODEL MEMBERS
$
'L1'  1       'L2'
'L2'  'L2'    'L3'
'L3'  'L3'    'L4'
'L4'  'L4'    'L5'
'L5'  'L5'    'L65'
'L6'  'L67'   'L7'
'L7'  'L7'    'L8'
'L8'  'L8'    'L98'
'L9'  'L910'  'L109'
'L10' 'L611'  'L116'
'L11' 'L1110' 'L1011'
'L12' 'L1112' 'L12'
'L13' 'L12'   'L1312'
$
$ LEFTSIDE RIGID LINKS AT RIGID BLOCKS
$
'LL56'   'L65'   'L6'
'LL67'   'L6'    'L67'
'LL89'   'L98'   'L9'
'LL910'  'L9'    'L910'
'LL109'  'L109'  'L10'
'LL611'  'L6'    'L611'
'LL116'  'L116'  'L11'
'LL1110' 'L11'   'L1110'
'LL1011' 'L1011' 'L10'
'LL1112' 'L11'   'L1112'
'LL1213' 'L1312' 'L13'
$
$ LEFTSIDE RIGID LINKS AT PILE HEADS
$
'LLP2'   'L2' 'LBP2'
'LLP310' 'L3' 'LBP310'
'LLP4'   'L4' 'LBP4'
'LLP511' 'L5' 'LBP511'
'LLP12'  'L6' 'LBP12'
'LLP613' 'L6' 'LBP613'
'LLP714' 'L7' 'LBP714'
'LLP8'   'L8' 'LBP8'
$
$ LEFTSIDE PILES (FICTITIOUS)
$
$ VERTICAL PILES
'LP2'  'LPB2'   'LBP2'
'LP3'  'LPB310' 'LBP310'
'LP4'  'LPB4'   'LBP4'
```

Figure B2. (Sheet 4 of 9)

```
'LP5'  'LPB5'   'LBP511'
'LP6'  'LPB6'   'LBP613'
'LP7'  'LPB7'   'LBP714'
'LP8'  'LPB8'   'LBP8'
'LP10' 'LPB310' 'LBP310'
$ BATTERED PILES
'LP11' 'LPB11' 'LBP511'
'LP12' 'LPB12' 'LBP12'
'LP13' 'LPB13' 'LBP613'
'LP14' 'LPB14' 'LBP714'
$
MEMBER PROPERTIES
$
$ CUFRAM MODEL PRISMATIC MEMBERS
'R1' 'R2' 'R3' 'R4' 'R5' 'R10' 'L1' 'L2' 'L3' 'L4' 'L5' 'L10'   -
PRISMATIC AX 48 AY 40 IZ 256
'R6' 'R7' 'R8' 'L6' 'L7' 'L8' PRISMATIC AX 36 AY 30 IZ 108
'R9' 'L9' 'R13' 'L13' PRISMATIC AX 24 AY 20 IZ 32
$ CUFRAM TAPERED MEMBERS
'R11' 'L11' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.81609E9   0            0
ROW 2 0            1.75000E8  -8.52658E8
ROW 6 0           -8.52658E8   7.52690E9
'R12' 'L12' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.83934E9   0            0
ROW 2 0            9.68873E7  -5.04735E8
ROW 6 0           -5.04735E8   4.98818E9
$ RIGID LINKS
'RL56' 'RL67' 'RL89' 'RL910' 'RL109' 'RL611' 'RL116' 'RL1110' 'RL1011'
'RL1112' 'RL1213' 'LL56' 'LL67' 'LL89' 'LL910' 'LL109' 'LL611' 'LL116'
'LL1110' 'LL1011' 'LL1112' 'LL1213' 'LP19' 'RLP2' 'RLP310' 'RLP4'   -
'RLP511' 'RLP12' 'RLP613' 'RLP714' 'RLP8' 'LLP2' 'LLP310' 'LLP4'   -
'LLP511' 'LLP12' 'LLP613' 'LLP714' 'LLP8' PRISMATIC AX 2.E4 IZ 1.E5
$ PILES
'P1' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' 'RP8' 'P9' 'RP10' 'RP11'   -
'RP12' 'RP13' 'RP14' 'LP2' 'LP3' 'LP4' 'LP5' 'LP6' 'LP7' 'LP8'   -
'LP10' 'LP11' 'LP12' 'LP13' 'LP14' STIFFNESS MATRIX COLUMNS 1 2 6
ROW 1 1.7928E7  0          0
ROW 2 0          2.6532E5  0
ROW 6 0          0          0
CONSTANTS E 4.32E8 ALL
CONSTANTS G 1.8E8 ALL
$
LOADING 1
$
JOINT LOADS
$ LOADS ON RIGHTSIDE RIGID BLOCKS
'R6'  FORCE X -1.72500E4 Y  8.34000E4 MOMENT Z  5.15000E4
'R9'  FORCE X -1.74830E5 Y  4.89000E4 MOMENT Z -1.06056E4
'R10' FORCE X -8.97800E4 Y -1.11276E5 MOMENT Z  4.90002E3
'R11' FORCE X  4.85625E4 Y -5.04000E4 MOMENT Z  1.07187E4
'R13' FORCE X -1.04469E4 Y -5.75143E4 MOMENT Z -6.95503E3
$ LOADS ON LEFTSIDE RIGID BLOCKS
'L6'  FORCE X  1.72500E4 Y  8.34000E4 MOMENT Z -5.15000E4
'L9'  FORCE X  1.48478E5 Y  4.89000E4 MOMENT Z  1.06056E4
'L10' FORCE X  6.89180E4 Y -8.19960E4 MOMENT Z -2.77329E3
'L11' FORCE X -4.85625E4 Y -5.04000E4 MOMENT Z -1.07187E4
```

Figure B2. (Sheet 5 of 9)

```
'L13' FORCE           Y -6.60375E4
$
$ EQUIVALENT JOINT LOADS FOR MEMBER LOADS ON TAPERED MEMBERS
$     AND NONUNIFORM MEMBER LOADS
$
$ RIGHTSIDE
'R910'  FORCE X -1.05598E5 Y -2.16000E4 MOMENT Z  2.08112E5
'R109'  FORCE X -9.94291E4 Y -2.16000E4 MOMENT Z -2.01943E5
'R1011' FORCE X -1.83251E4 Y -1.31798E5 MOMENT Z  2.83101E5
'R1110' FORCE X -1.95624E4 Y -1.51055E5 MOMENT Z -2.84064E5
'R1112' FORCE X -8.69417E4 Y -8.46301E4 MOMENT Z  1.87429E5
'R12'   FORCE X -7.74678E4 Y -8.22180E4 MOMENT Z -1.33959E5
'R1312' FORCE X -1.65961E4 Y -1.80000E4 MOMENT Z -3.14842E4
$ LEFTSIDE
'L910'  FORCE X 7.92641E4 Y -2.16000E4 MOMENT Z -1.55408E5
'L109'  FORCE X 7.30771E4 Y -2.16000E4 MOMENT Z  1.49239E5
'L1011' FORCE X 1.36089E4 Y -9.02758E4 MOMENT Z -1.95261E5
'L1110' FORCE X 1.43966E4 Y -1.04736E5 MOMENT Z  1.96224E5
'L1112' FORCE X 4.73295E4 Y -6.92708E4 MOMENT Z -9.94973E4
'L12'   FORCE X 2.78277E4 Y -6.82972E4 MOMENT Z  8.03831E4
'L1312' FORCE X 4.95298E2 Y -1.80000E4 MOMENT Z  1.46978E3
$
MEMBER LOADS
$
'R1' 'R2' 'R3' 'R4' 'R5' -
     FORCE Y UNIFORM W -1575
'L1' 'L2' 'L3' 'L4' 'L5' FORCE Y UNIFORM W -1575
'R6' 'R7' 'R8'  FORCE Y UNIFORM W 3225
'L6' 'L7' 'L8' FORCE Y UNIFORM W 3225
'R10' 'L10' FORCE X UNIFORM W -7200
'R10'       FORCE Y UNIFORM W -3750
'L10'       FORCE Y UNIFORM W 3750
$
LOADING LIST ALL
STIFFNESS ANALYSIS
```

Figure B2. (Sheet 6 of 9)

```
****************************
*RESULTS OF LATEST ANALYSES*
****************************

 PROBLEM - EX2B      TITLE - GTSTRUDL SOLUTION FOR TYPE 2 MONOLITH
 ACTIVE UNITS  FEET LB   RAD  DEGF SEC

$ RIGHTSIDE CUFRAM MODEL JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
1 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' 'R10' 'R11' 'R12' 'R13'
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	-.0155147	-.0013091	-.0000713
R2	-.0157974	-.0023690	-.0001369
R3	-.0160822	-.0040500	-.0001840
R4	-.0163712	-.0060422	-.0001437
R5	-.0166625	-.0068820	.0000861
R6	-.0167211	-.0060962	.0001627
R7	-.0166569	-.0043712	.0002334
R8	-.0167597	-.0030914	.0002823
R9	-.0168015	-.0019211	.0003056
R10	-.0217283	-.0020540	.0001925
R11	-.0219186	-.0064050	.0003613
R12	-.0314982	-.0075564	.0006430
R13	-.0415437	-.0061243	.0006557

```
$ LEFTSIDE CUFRAM MODEL JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
1 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' 'L10' 'L11' 'L12' 'L13'
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	-.0155147	-.0013091	-.0000713
L2	-.0152361	-.0009268	-.0000147
L3	-.0149594	-.0010014	.0000197
L4	-.0146866	-.0012991	.0000212
L5	-.0144156	-.0014080	-.0000213
L6	-.0143651	-.0012332	-.0000402
L7	-.0143079	-.0008284	-.0000334
L8	-.0142226	-.0007162	-.0000431
L9	-.0141889	-.0005317	-.0000591
L10	-.0129014	-.0006766	-.0000359
L11	-.0129248	-.0014667	-.0000902
L12	-.0106904	-.0017952	-.0000985
L13	-.0103507	-.0019003	.0000104

Figure B2. (Sheet 7 of 9)

```
$ RIGHTSIDE CUFRAM MODEL MEMBER END FORCES
LIST FORCES MEMBERS 'R1' 'R2' 'R3' 'R4' 'R5' 'R6' 'R7' 'R8' 'R9' -
'R10' 'R11' 'R12' 'R13' 'P1' 'RP2' 'RP3' 'RP4' 'RP5' 'RP6' 'RP7' -
'RP8' 'RP8' 'RP10' 'RP11' 'RP12' 'RP13' 'RP14'
```

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
R1	1	586149.7272804	16729.9559711	783391.6756335
R1	R2	-586149.7272804	-979.9559711	-694842.1159226
R2	R2	590485.4817036	43451.4426638	712185.1423912
R2	R3	-590485.4817036	-27701.4426638	-356420.7157528
R3	R3	599408.0771699	172917.9012942	392111.0986977
R3	R4	-599408.0771699	-157167.9012942	1258317.9142443
R4	R4	603903.2386186	265494.3495158	-1240337.2591007
R4	R5	-603903.2386186	-249744.3495158	3816530.7542583
R5	R5	604916.1328304	397884.5697290	-3812479.1773512
R5	R65	-604916.1328304	-394734.5697290	4605098.3168091
R6	R67	306258.7494014	-80617.4777620	-846190.0637415
R6	R7	-306258.7494014	64492.4777620	483415.1749313
R7	R7	319746.7051046	-32.5245938	-442951.3242411
R7	R8	-319746.7051046	-16092.4754062	483101.2012721
R8	R8	323967.8413243	71515.6729182	-470437.7938913
R8	R98	-323967.8413243	-77965.6729182	619919.1397276
R9	R910	105265.6752848	-43539.8469113	-130930.5581843
R9	R109	-105265.6752848	43539.8469113	-391547.6047515
R10	R611	675225.7244596	-288946.7110125	-3698308.6911051
R10	R116	-603225.7244596	326446.7110125	621341.5809805
R11	R1110	148399.0612023	174019.7297408	1817739.6702741
R11	R1011	-148399.0612023	-174019.7297408	279653.8325137
R12	R1112	143061.0171975	123836.7117821	1954203.6345737
R12	R12	-143061.0171975	-123836.7117821	-18821.6330206
R13	R12	75514.3000892	-27043.0000886	-152780.6330199
R13	R1312	-75514.3000892	27043.0000886	-117649.3678665
$ RIGHTSIDE PILE FORCES				
P1	BP19	-23469.3474605	4191.1187096	0.0000000
RP2	RBP2	-42471.4867691	4335.7561306	0.0000000
RP3	RBP310	-72608.2293258	4461.2965441	0.0000000
RP4	RBP4	-108326.4484280	4495.1634121	0.0000000
RP5	RBP511	-123381.9317710	4328.5722920	0.0000000
RP6	RBP613	-97621.6548686	4262.8102634	0.0000000
RP7	RBP714	-78367.6054593	4232.7800792	0.0000000
RP8	RBP8	-55423.1974828	4221.1342866	0.0000000
P9	BP19	-23469.3474605	4191.1187096	0.0000000
RP10	RBP310	-72608.2293258	4461.2965441	0.0000000
RP11	RBP511	-24536.2852327	-4683.7266772	0.0000000
RP12	RBP12	-15345.0113566	-4569.0897155	0.0000000
RP13	RBP613	-1503.4652826	-4500.8115172	0.0000000
RP14	RBP714	16120.6980334	-4382.2360595	0.0000000

Figure B2. (Sheet 8 of 9)

```
$ LEFTSIDE CUFRAM MODEL MEMBER END FORCES AND LEFTSIDE PILE FORCES
LIST FORCES MEMBERS 'L1' 'L2' 'L3' 'L4' 'L5' 'L6' 'L7' 'L8' 'L9' -
'L10' 'L11' 'L12' 'L13' 'P1' 'LP2' 'LP3' 'LP4' 'LP5' 'LP6' 'LP7' -
'LP8' 'LP9' 'LP10' 'LP11' 'LP12' 'LP13' 'LP14'
```

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
L1	1	577767.4879841	30208.7389502	749862.7169951
L1	L2	-577767.4879841	-14458.7389502	-526525.3274935
L2	L2	573710.2532698	31075.4190981	510296.3759735
L2	L3	-573710.2532698	-15325.4190981	-278292.1849929
L3	L3	565815.7013132	51231.6298173	246713.9760299
L3	L4	-565815.7013132	-35481.6298173	186852.3221433
L4	L4	561942.4215249	58771.4713978	-202345.4490539
L4	L5	-561942.4215249	-43021.4713978	711310.1630322
L5	L5	521176.2939724	167856.6326999	-874374.6751158
L5	L65	-521176.2939724	-164706.6326999	1206937.9405155
L6	L67	302607.3155569	-60073.5189728	-72956.7684840
L6	L7	-302607.3155569	43948.5189728	-187098.3263801
L7	L7	265124.6565221	60639.6420522	74650.3549613
L7	L8	-265124.6565221	-76764.6420522	268860.3552999
L8	L8	261317.6107162	89604.8739961	-280281.4877280
L8	L98	-261317.6107162	-96054.8739961	465941.2357203
L9	L910	123354.8729295	33575.5091319	174729.7692642
L9	L109	-123354.8729295	-33575.5091319	228176.3403189
L10	L611	519258.4268665	126015.0804996	1244229.6070071
L10	L116	-447258.4268665	-163515.0804996	203421.1979892
L11	L1110	114913.6369134	81599.2910535	768679.5307422
L11	L1011	-114913.6369134	-81599.2910535	214805.6358112
L12	L1112	147457.6518165	47584.5979456	515191.5135846
L12	L12	-147457.6518165	-47584.5979456	228484.3567593
L13	L12	84037.4999872	495.2980883	-148101.2567595
L13	L1312	-84037.4999872	-495.2980883	153054.2376427
$ LEFTSIDE PILE FORCES				
P1	BP19	-23469.3474605	4191.1187096	0.0000000
LP2	LBP2	-16616.6801764	4057.2375503	0.0000000
LP3	LBP310	-17953.1053579	3947.2748839	0.0000000
LP4	LBP4	-23289.8416128	3873.2813801	0.0000000
LP5	LBP511	-25242.1847776	3846.4792269	0.0000000
LP6	LBP613	-19223.3059603	3853.2166920	0.0000000
LP7	LBP714	-14852.0387154	3821.9324087	0.0000000
LP8	LBP8	-12840.2319136	3807.0320679	0.0000000
P9	BP19	-23469.3474605	4191.1187096	0.0000000
LP10	LBP310	-17953.1053579	3947.2748839	0.0000000
LP11	LBP511	-106157.2105241	3530.9868393	0.0000000
LP12	LBP12	-104013.0920900	3548.6569275	0.0000000
LP13	LBP613	-100591.1998068	3565.5398392	0.0000000
LP14	LBP714	-95775.6160843	3556.3133557	0.0000000.

Figure B2. (Sheet 9 of 9)

```
STRUDL 'CUEX3' 'GTSTRUDL SOLUTION FOR TYPE 31 MONOLITH'
TYPE PLANE FRAME
UNITS FEET
JOINT COORDINATES
$  CUFRAM MODEL JOINTS
1   0      367   S
2   5.5    367
3  11      367
4  16.5    367
5  22      367
6  27.5    367
7  33      367
8  38.5    367
9  44      367
10 50.5    367
11 55      367
12 59.04   367          $ RIGID BLOCK 2
13 64      366
14 68.5    366
15 73      366
16 77.5    366
17 83.875 366           $ RIGID BLOCK 1
18 83.875 394.5         $ RIGID BLOCK 4
19 86.21  432           $ RIGID BLOCK 6
20 59.04  394.5         $ RIGID BLOCK 3
21 57.54  432           $ RIGID BLOCK 5
$ JOINTS AT ENDS OF FLEXIBLE LENGTHS
1211 55.04  367
1213 63.04  366
1716 79.04  366
1718 83.875 374
1817 83.875 392
1819 86.21  397
1918 86.21  429.5
1220 59.04  376
2012 59.04  392
2018 63.04  394.5
1820 79.04  394.5
2021 57.54  397
2120 57.54  429.5
2119 60.04  432
1921 83.71  432
$ JOINTS ON BASE AT PILE HEADS
'BP121'   0      358
'BP222'   5.5    358
'BP323'  11      358
'BP424'  16.5    358
'BP525'  22      358
'BP6'    27.5    358
'BP26'   33      358
'BP7'    38.5    358
'BP27'   44      358
'BP8'    50.5    358
'BP28'   55      358
'BP9'    59.5    358
```

Figure B3. GTSTRUDL solution for CUFRAM Example 3--type 31 monolith with pile supports (Sheet 1 of 7)

```
'BP29'    64      358
'BP10'    68.5    358
'BP1130'  73      358
'BP1231'  77.5    358
'BP1332'  82      358
'BP1433'  86.5    358
$ JOINTS AT BOTTOMS OF PILES (FICTITIOUS)
'PB121'    0      348 S
'PB222'    5.5    348 S
'PB323'   11      348 S
'PB424'   16.5    348 S
'PB525'   22      348 S
'PB6'     27.5    348 S
'PB26'    33      348 S
'PB7'     38.5    348 S
'PB27'    44      348 S
'PB8'     50.5    348 S
'PB28'    55      348 S
'PB9'     59.5    348 S
'PB29'    64      348 S
'PB10'    68.5    348 S
'PB1130'  73      348 S
'PB1231'  77.5    348 S
'PB1332'  82      348 S
'PB1433'  86.5    348 S
JOINT 1 RELEASES FORCE Y
MEMBER INCIDENCES
$ CUFRAM MODEL MEMBERS
 1    1    2
 2    2    3
 3    3    4
 4    4    5
 5    5    6
 6    6    7
 7    7    8
 8    8    9
 9    9   10
10   10   11
11   11 1211
12 1213   13
13   13   14
14   14   15
15   15   16
16   16 1716
17 1718 1617
18 1819 1918
19 1220 2012
20 2021 2120
21 2018 1820
22 2119 1921
$ RIGID LINKS AT RIGID BLOCKS
1112 1211   12
1213   12 1213
1617 1716   17
1718   17 1718
```

Figure B3. (Sheet 2 of 7)

```
1817 1817   18
1819   18 1819
1918 1918   19
1220   12 1220
2012 2012   20
2021   20 2021
2120 2120   21
2018   20 2018
1820 1820   18
2119   21 2119
1921 1921   19
$ RIGID LINKS AT PILE HEADS
'LP121'    1 'BP121'
'LP222'    2 'BP222'
'LP323'    3 'BP323'
'LP424'    4 'BP424'
'LP525'    5 'BP525'
'LP6'      6 'BP6'
'LP26'     7 'BP26'
'LP7'      8 'BP7'
'LP27'     9 'BP27'
'LP8'     10 'BP8'
'LP28'    11 'BP28'
'LP9'     12 'BP9'
'LP29'    13 'BP29'
'LP10'    14 'BP10'
'LP1130'  15 'BP1130'
'LP1231'  16 'BP1231'
'LP1332'  17 'BP1332'
'LP1433'  17 'BP1433'
$ PILES (FICTITIOUS)
'P1'  'PB121'  'BP121'
'P2'  'PB222'  'BP222'
'P22' 'PB222'  'BP222'
'P3'  'PB323'  'BP323'
'P23' 'PB323'  'BP323'
'P4'  'PB424'  'BP424'
'P24' 'PB424'  'BP424'
'P5'  'PB525'  'BP525'
'P25' 'PB525'  'BP525'
'P6'  'PB6'    'BP6'
'P26' 'PB26'   'BP26'
'P7'  'PB7'    'BP7'
'P27' 'PB27'   'BP27'
'P8'  'PB8'    'BP8'
'P28' 'PB28'   'BP28'
'P9'  'PB9'    'BP9'
'P29' 'PB29'   'BP29'
'P10' 'PB10'   'BP10'
'P11' 'PB1130' 'BP1130'
'P30' 'PB1130' 'BP1130'
'P12' 'PB1231' 'BP1231'
'P31' 'PB1231' 'BP1231'
'P13' 'PB1332' 'BP1332'
'P32' 'PB1332' 'BP1332'
```

Figure B3. (Sheet 3 of 7)

```
'P32'  'PB1332'  'BP1332'
'P14'  'PB1433'  'BP1433'
'P33'  'PB1433'  'BP1433'
MEMBER PROPERTIES
$ CUFRAM MODEL MEMBERS
1 2 3 4 5 6 7 8 9 10 11 -
             PRISMATIC AX 162    AY 135     IZ 4374
12 13 14 15 16 -
             PRISMATIC AX 144    AY 120     IZ 3072
19           PRISMATIC AX 72     AY 60      IZ 384
17           PRISMATIC AX 87.03  AY 72.525  IZ 678.1733
18 20 21 22  PRISMATIC AX 45     AY 37.5    IZ 93.75
$ RIGID LINKS
1112 1213 1617 1718 1817 1819 1918 1220 2012 2021 2120 2018 -
1820 2119 1921 'LP121' 'LP222' 'LP323' 'LP424' 'LP525' 'LP6' -
'LP26' 'LP7' 'LP27' 'LP8' 'LP28' 'LP9' 'LP29' 'LP10' 'LP1130' -
'LP1231' 'LP1332' 'LP1433' PRISMATIC AX 6 5E4 IZ 1 75E6
$ PILES
 'P1' 'P2' 'P3' 'P4' 'P5' 'P6' 'P22' 'P23' 'P24' 'P25' 'P26' -
     STIFFNESS MATRIX COLUMNS 1 2 6
 ROW 1 2 40E8  0          0
 ROW 2 0       6 588E6 -2 770000E6
 ROW 6 0      -2 770E6  1 933333E6
 'P7' 'P8' 'P9' 'P10' 'P11' 'P12' 'P13' 'P14' 'P27' 'P28' -
 'P29' 'P30' 'P31' 'P32' 'P33' STIFFNESS MATRIX COLUMNS 1 2 6
 ROW 1 2 40E8  0          0
 ROW 2 0       9 876E6  -5 090000E6
 ROW 6 0      -5 090E6   4 358333E6
CONSTANTS E 4 32E8 ALL
CONSTANTS G 1 80E8 ALL
LOADING 1
JOINT LOADS
$ LOADS ON RIGID BLOCKS
12      FORCE X -2 25000E4 Y  9 36000E4 MOMENT Z  1 79625E5
17      FORCE X -6 35220E5 Y  1 39248E5 MOMENT Z -2 88000E5
18      FORCE X -8 25188E4 Y -6.52725E4 MOMENT Z -1 01719E4
19 21 FORCE                Y -3.37500E4
20      FORCE X  2.53125E3 Y -5.40000E4 MOMENT Z  3.79688E3
$ EQUIVALENT JOINT LOADS FOR NONUNIFORM MEMBER LOADS
1718   FORCE X -2 02265E5 Y -1.17491E5 MOMENT Z  5 86675E5
1817   FORCE X -1 75438E5 Y -1.17491E5 MOMENT Z -5 46434E5
1819   FORCE X -1 39777E5 Y -1.09688E5 MOMENT Z  5 98072E5
1918   FORCE X -3 60044E4 Y -1 09688E5 MOMENT Z -3 03370E5
MEMBER LOADS
$ UNIFORM MEMBER LOADS
1 2 3 4 5 6 7 8 9 10 11 FORCE Y UNIFORM W 1012 5
12 13 14 15 16          FORCE Y UNIFORM W 2587 5
19      FORCE X UNIFORM W -10800
20      FORCE X UNIFORM W -6750
21      FORCE Y UNIFORM W -5062.5
22      FORCE Y UNIFORM W -6750

LOADING LIST ALL
STIFFNESS ANALYSIS
```

Figure B3. (Sheet 4 of 7)

```
******************************
*RESULTS OF LATEST ANALYSES*
******************************

 PROBLEM - CUEX3     TITLE - GTSTRUDL SOLUTION FOR TYPE 31 MONOLITH
 ACTIVE UNITS  FEET LB   RAD  DEGF SEC

$ CUFRAM JOINT DISPLACEMENTS
LIST DISPLACEMENTS JOINTS -
 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
```

JOINT	X DISP.	Y DISP.	Z ROT.
1	0.0000000	.0000234	0.0000000
2	-.0000901	.0000198	-.0000016
3	-.0001803	.0000081	-.0000032
4	-.0002708	-.0000137	-.0000051
5	-.0003615	-.0000487	-.0000070
6	-.0004527	-.0001007	-.0000088
7	-.0005442	-.0001674	-.0000099
8	-.0006360	-.0002469	-.0000096
9	-.0007284	-.0003343	-.0000072
10	-.0008363	-.0004315	-.0000001
11	-.0009149	-.0004825	.0000087
12	-.0009158	-.0004477	.0000088
13	-.0009219	-.0004003	.0000102
14	-.0009921	-.0003477	.0000166
15	-.0010629	-.0002844	.0000240
16	-.0011349	-.0002133	.0000341
17	-.0011601	.0000010	.0000385
18	-.0031909	-.0001900	.0000648
19	-.0070274	-.0003899	.0000887
20	-.0030238	-.0007935	.0001110
21	-.0069991	-.0013557	.0000072

Figure B3. (Sheet 5 of 7)

$ CUFRAM MODEL MEMBER FORCES
LIST FORCES MEMBERS -
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
1	1	1146546.0601721	-5616.6483490	527531.0716073
1	2	-1146546.0601721	47.8983490	-543108.5750268
2	2	1147927.6226504	-9531.694 5548	556125.9377995
2	3	-1147927.6226504	3962.9445548	-593236.1953509
3	3	1150706.3989491	-7853.4220350	619418.5398918
3	4	-1150706.3989491	2284.6720350	-647298.2985840
4	4	1154906.4658888	4266.7444567	686872.7023437
4	5	-1154906.4658888	-9835.4944567	-648091.5453318
5	5	1160544.5011071	33204.9045773	701215.2717528
5	6	-1160544.5011071	-38773.6545773	-503274.2340778
6	6	1164073.6457117	62940.5436913	536527.1746451
6	7	-1164073.6457117	-68509.2936913	-175040.1218432
7	7	1168270.2158813	108675.0807635	214581.3205026
7	8	-1168270.2158813	-114243.8307635	398445.6861965
8	8	1175452.7757167	173489.8464803	-330084.1834609
8	9	-1175452.7757167	-179058.5964803	1299592.4016025
9	9	1183325.4732491	259287.4676565	-1224668.0714164
9	10	1183325.4732491	-265868.7176565	2931425.6736837
10	10	1191612.9870846	369422.1765042	-2852566.5844454
10	11	-1191612.9870846	-373978.4265042	4525217.9412141
11	11	1199832.0250229	489764.7194339	-4447025.6618804
11	1211	1199832.0250229	-489805.2194339	4466617.0606577
12	1213	961816.4797755	-68190.7586369	-1945413.9337789
12	13	-961816.4797755	65706.7586369	1881143.1254875
13	13	970063.1808461	30363.0858676	-1810936.9508873
13	14	-970063.1808461	-42007.0358676	1973770.1747916
14	14	978464.5199117	125456.3544247	-1902258.3046306
14	15	-978464.5199117	-137100.1044247	2493010.3370416
15	15	995414.3234740	273572.7979693	-2348759.5749153
15	16	-995414.3234740	-285216.5479693	3606035.6032773
16	16	1012090.7988636	387574.1203003	-3464147.3155861
16	1716	-1012090.7988636	-391558.8703003	4064079.7183486
17	1718	398514.6398924	-207475.4548272	-2293799.6204932
17	1817	-398514.6398924	207475.4548272	-1440758.5663971
18	1819	210027.1983823	-12708.8257724	-236318.7046525
18	1918	-210027.1983823	12708.8257724	-176718.1329506
19	1220	758072.3526359	-223731.4694016	-2849127.6779422
19	2012	-585272.3526359	223731.4694016	-730575.8324835
20	2021	346308.3094951	-23295.5712390	-249227.7957119
20	2120	-126933.3094951	23295.5712390	-507878.2695550
21	2018	202967.1566813	184964.0546178	1380774.4330935
21	1820	-202967.1566813	-103964.0546178	930650.4407921
22	2119	23295.5575229	93183.3035908	333158.9549112
22	1921	-23295.5575229	66589.1964092	-18417.6964164

Figure B3. (Sheet 6 of 7)

```
$ PILES
 LIST FORCES MEMBERS 'P1' 'P2' 'P3' 'P4' 'P5' 'P6' 'P7' 'P8' -
 'P9' 'P10' 'P11' 'P12' 'P13' 'P14' 'P21' 'P22' 'P23' 'P24' -
 'P25' 'P26' 'P27' 'P28' 'P29' 'P30' 'P31' 'P32' 'P33'
```

MEMBER	JOINT	AXIAL	SHEAR Y	BENDING Z
P1	BP121	5616.6483491	0.0000000	0.0000000
P2	BP222	4741.8981033	690.7812426	-291.6502189
P3	BP323	1945.2387402	1389.3881585	-586.6788952
P4	BP424	-3275.7082461	2100.0334886	-886.9005407
P5	BP525	-11684.7050615	2819.0176263	-1190.7046786
P6	BP6	-24166.8891170	3529.1446502	-1490.6389435
P7	BP7	-59246.0157230	7182.5598844	-3718.4638901
P8	BP8	-103553.4588502	8287.5139464	-4271.4638026
P9	BP9	-106476.3725263	8215.9230519	-4219.1173198
P10	BP10	-83449.3185584	8401.3392780	-4301.1564349
P11	BP1130	-68236.3467800	8474.9019621	-4326.1660706
P12	BP1231	-51178.7861683	8338.2377983	-4238.2400273
P13	BP1332	-17100.9733084	8217.4153264	-4168.3368701
P14	BP1433	24501.5886831	8217.4121682	-4168.3358461
P22	BP222	4741.8981033	690.7812426	-291.6502189
P23	BP323	1945.2387402	1389.3881585	-586.6788952
P24	BP424	-3275.7082461	2100.0334886	-886.9005407
P25	BP525	-11684.7050615	2819.0176263	-1190.7046786
P26	BP26	-40165.7870756	4196.5701696	-1772.0673303
P27	BP27	-80228.8711792	7872.6975343	-4070.0523393
P28	BP28	-115786.2929312	8219.0380560	-4220.9369567
P29	BP29	-96070.0445070	8246.7012622	-4232.5646264
P30	BP1130	-68236.3467800	8474.9019621	-4326.1660706
P31	BP1231	-51178.7861683	8338.2377983	-4238.2400273
P32	BP1332	-17100.9733084	8217.4153264	-4168.3368701
P33	BP1433	24501.5886831	8217.4121682	-4168.3358461

Figure B3. (Sheet 7 of 7)

APPENDIX C: NOTATION

A	Pile cross-sectional area
AC	Allowable pile axial compression force (KIPS)
AM	Allowable bending moment (KIP-FT)
AT	Allowable pile axial tension force (KIPS)
ACC	Allowable pile axial compression force for combined axial compression and bending (KIPS)
ATT	Allowable pile axial tension force for combined axial tension and bending (KIPS)
A_{ξ}	Cross-sectional area at ξ
$A_{v\xi}$	Shear area at ξ
BATTER	Slope of pile vertical (FT) per foot horizontal
BM	Bending moment at pile head for nonpinned head piles FPM*FV where FV = pile head shear for pinned head piles
BPR(I)	Base soil pressure (PSF) at i^{th} pressure point
B_{11}	Pile lateral stiffness (LB/IN.)
B_{22}	Pile axial stiffness (LB/IN.)
B_{33}	Pile moment stiffness (LB/IN.)
B_{13}	Lateral force-moment coupling stiffness (LB)
CULHGT	Height of culvert opening
CULWID	Width of culvert opening
[CULFIL]	Width of 45-deg fillet in culvert corners
c_x	Cosine of angle between local x and global x
c_y	Cosine of angle between local x and global y
C_{α}	Cosine of α

* The terms "rightside," leftside," and "centerline" are each used in a one-word form in the Notation to be consistent with these terms as used in the computer program.

d_L, d_R	Distances from chamber centerline* to line of action of leftside* and rightside* vertical shear forces
$\underset{\sim}{D}$	6x6 rigid link transformation matrix
D_f	Pile head fixity coefficient
D_i	Horizontal distance from stem face
DBASE(1)	Distance from chamber centerline to first base point
[DBASE(2), ELBASE(2)]	Distance from chamber centerline to second base point and elevation at second base point
DBPR(I)	Distance (FT) from chamber centerline to i^{th} pressure point
DCUL	Distance from inside stem face to interior vertical side of culvert
DSTART	Distance from chamber centerline to intersection of pile centerline with base of structure (FT)
DSTEM	Distance from inside face of stem to i^{th} stem point
[DSTEP]	Distance between adjacent piles in the sequence (FT)
DUPR(I)	Distance (FT) from chamber centerline to i^{th} pressure point
DVOID	Distance from inside stem face to interior vertical
DCFBLD	Distance from chamber centerline at which load acts (FT)
DCSTLD	Distance from inside stem face at which load acts (FT)
DDFBLD(I)	Distance from chamber centerline to i^{th} load point (FT)
DDSTLD(I)	Distance from inside stem face to i^{th} load point (FT)
E	Modulus of elasticity of pile material
E_i	Elevation for i^{th} stem point
EC	Modulus of elasticity of concrete
ELPR(I)	Elevation (FT) of i^{th} pressure point
[ELGW]	Elevation (FT) of ground-water surface
ELCUL	Elevation of floor of culvert
ELLAY	Elevation (FT) at top of layer
ELTIE	Elevation at top of i^{th} tie member

ELCHMW	Elevation of chamber water
EHSPR(I)	Effective horizontal soil pressure (PSF) at i^{th} pressure point
ESSPR(I)	Effective soil shear stress (PSF) at i^{th} pressure point
EVSPR(I)	Effective vertical soil pressure (PSF) at i^{th} pressure point
[ELCWL]	Effective water elevation in leftside culvert (and stem void) (FT)
[ELCWR]	Effective water elevation in rightside culvert (and stem void) (FT)
ELVOID	Elevation of bottom of void opening
ELCSLD(I)	Elevation at which load acts (FT)
ELDSLD(I)	Elevation at load point (FT)
ELFLOR	Elevation of chamber floor
ELSTEM(I)	Elevation at i^{th} stem point (FT)
ELWPRE(I)	Elevation (FT) at i^{th} pressure point
[ELSURW]	Elevation (FT) of surcharge water surface
f_{xp}	Pile head shear force
f_{yp}	Pile head axial force
$\underset{\sim}{F}$	3nx1 vector of loads applied directly to the joints including the static equivalents of surface loads acting on the rigid blocks and necessary equilibrants of unbalanced vertical and/or moment resultants arising from user-supplied soil base pressure
$\underset{\sim}{F}_{ab}$	6x1 vector of global force components at $\underline{a}$ and $\underline{b}$
$\underset{\sim}{F}_{e}$	3nx1 vector of fixed end forces
$\underset{\sim}{F}_{eab}$	6x1 vector of fixed end forces at ends of the flexible length in local coordinate directions
$\underset{\sim}{F}_{eij}$	6x1 vector of fixed end forces at joints i and j in global coordinate directions
[FLRFIL]	Width of 45-deg fillet at floor-stem intersection
FLRWID	Distance from chamber centerline to inside face of stem

FMM	Moment magnification factor for amplification effect of axial compression on bending moment
FPM	Factor (IN.) for evaluating maximum bending moment in pinned head pile
G	Shear modulus
GAMMST	Moist soil unit weight
GAMSAT	Saturated soil unit weight
[GAMWAT]	Unit weight of water (PCF)
HCFBLD	Magnitude of horizontal load component (PLF)
HCSTLD	Magnitude of horizontal load component (PLF)
HCSLD(I)	Magnitude of horizontal load component (PLF)
HDSLD(I)	Magnitude of horizontal load at i^{th} load point (PSF)
HDFBLD(I)	Magnitude of horizontal load at i^{th} load point (PSF)
HDSTLD(I)	Magnitude of horizontal load at i^{th} load point (PLF)
HTIE(I)	Depth of i^{th} tie member
I	Pile cross-sectional moment of inertia
I_ξ	Cross-sectional moment of inertia at ξ
$\underset{\sim}{k}$	Global stiffness matrix
$\underset{\sim}{k}'$	Local stiffness matrix
k_A	Axial stiffness coefficient
KHB, KHT	Horizontal pressure coefficients at bottom and top of layer, respectively
KVB, KVT	Shear coefficients at bottom and top of layer, respectively
ℓ	Width of structure base
L	Pile length
M_p	Pile head moment
M_1	Moment resultant about chamber floor centerline
M_3	Unbalanced moment

M_ξ	Bending moment at ξ
NLDS	Number (1 to 10) of concentrated loads
NPTS	Number (2 to 21) of points on input pressure distribution
NSTART	Pile number at start of sequence
[NSTEP]	Step in pile number
[NSTOP]	Pile number of last pile in sequence
NTIES	Number (0 to 5) of horizontal structural members across void opening
NUM	Number (1 to 5) of horizontal soil layers of 'type' = 'Soil'
OSFC	Load case factor for pile in compression
OSFT	Load case factor for pile in tension
p_{actual}	Adjusted base pressure
p_{input}	User-specified pressure
p_u	Uniform base pressure
p_x	Pressure due to unbalanced moment
p_1	Base pressure at chamber centerline
p_2	Base pressure at extreme edge of base
PA	Pile cross-sectional area (IN.^{2})
PAXCO	Coefficient for pile axial stiffness
PCT	Fraction of uniform base reaction to be applied at chamber centerline
PE	Pile modulus of elasticity (PSI)
PI	Pile moment of inertia (IN.^{4})
PL	Pile length (FT)
PR	Poisson's ratio for concrete
P_ξ	Actual stress resultant at ξ
R	Factor prescribed by user
$\underset{\sim}{R}$	Transformation matrix

$\underset{\sim}{R}^T$	Transpose of $\underset{\sim}{R}$
[RLF]	Rigid block reduction factor for member flexible length ($0 \le RLF \le 1$)
SCHT, SCHB	Coefficient for horizontal soil pressure at top and bottom of layer
[SCVT, SCVB]	Coefficient for soil shear stress at top and bottom of layer
[SURCH]	Surface surcharge load
S_1, S_2	Soil stiffness coefficients for lateral resistance
S_α	Sine of α
SS_1	Constant soil stiffness coefficient (LB/IN.^{2})
SS_2	Linear soil stiffness coefficient (LB/IN.^{3})
u_p, v_p	Translation components of displacement perpendicular and parallel to the pile axis
$\underset{\sim}{U}$	3nx1 vector of joint displacements
$\underset{\sim}{U}_{ab}$	6x1 vector of global displacement components at $\underline{a}$ and $\underline{b}$
[UPLEFT]	Effective uplift water elevation at extreme leftside of base (FT)
UPR(I)	Uplift pressure (PSF) at i^{th} pressure point
[UPRITE]	Effective uplift water elevation at extreme rightside of base (FT)
V	Net vertical reaction of applied loads
V_u	Vertical resultant of user-specified base pressure distribution
V_R, V_L	Resultants of vertical stem shear forces
V*, M*	Vertical and moment unbalances remaining after combining resultants of applied loads and user-supplied base reaction
VCFBLD	Magnitude of vertical load component, pounds per linear foot (PLF)
VCSLD(I)	Magnitude of vertical load component (PLF)
VCSTLD(I)	Magnitude of vertical load component (PLF)
VDFBLD(I)	Magnitude of vertical load at i^{th} load point (PSF)

VDSLD(I)	Magnitude of vertical load at i^{th} load point (PSF)
VDSTLD(I)	Magnitude of vertical load at i^{th} load point (PLF)
VOIDHT	Height of void opening
VOIDWD	Width of void opening
V_ξ	Shear force at ξ
WPRE(I)	Pressure (PSF) at i^{th} pressure point
WTCONC	Unit weight of concrete
x	Distance from base centerline, positive to the right
(γ_{MST}) (PCF)	Moist soil unit weight
(γ_{SAT}) (PCF)	Saturated soil unit weight
θ_p	Pile head notation
σ	+1 for loads on top surface 0 for self weight of member -1 for loads on bottom surface

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	[illegible]
	Report 3: General Analysis Module (CGAM)	[illegible]
	Report 4: Special-Purpose Modules for Dams (CDAMS)	[illegible]
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	[illegible]
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	[illegible]
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	[illegible]
	Report 2: Anchored Wall Monolith, Bay Springs Lock	[illegible]
Technical Report K-80-5	Basic Pile Group Behavior	[illegible]
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	[illegible]
	Report 2: Interactive Graphics Options	[illegible]
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	[illegible]
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	[illegible]
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	[illegible]
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

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(Concluded)

	Title	Date
Instruction Report K-83-1	User's Guide: Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-8[illegible]	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-[illegible]	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-[illegible]	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-[illegible]	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
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